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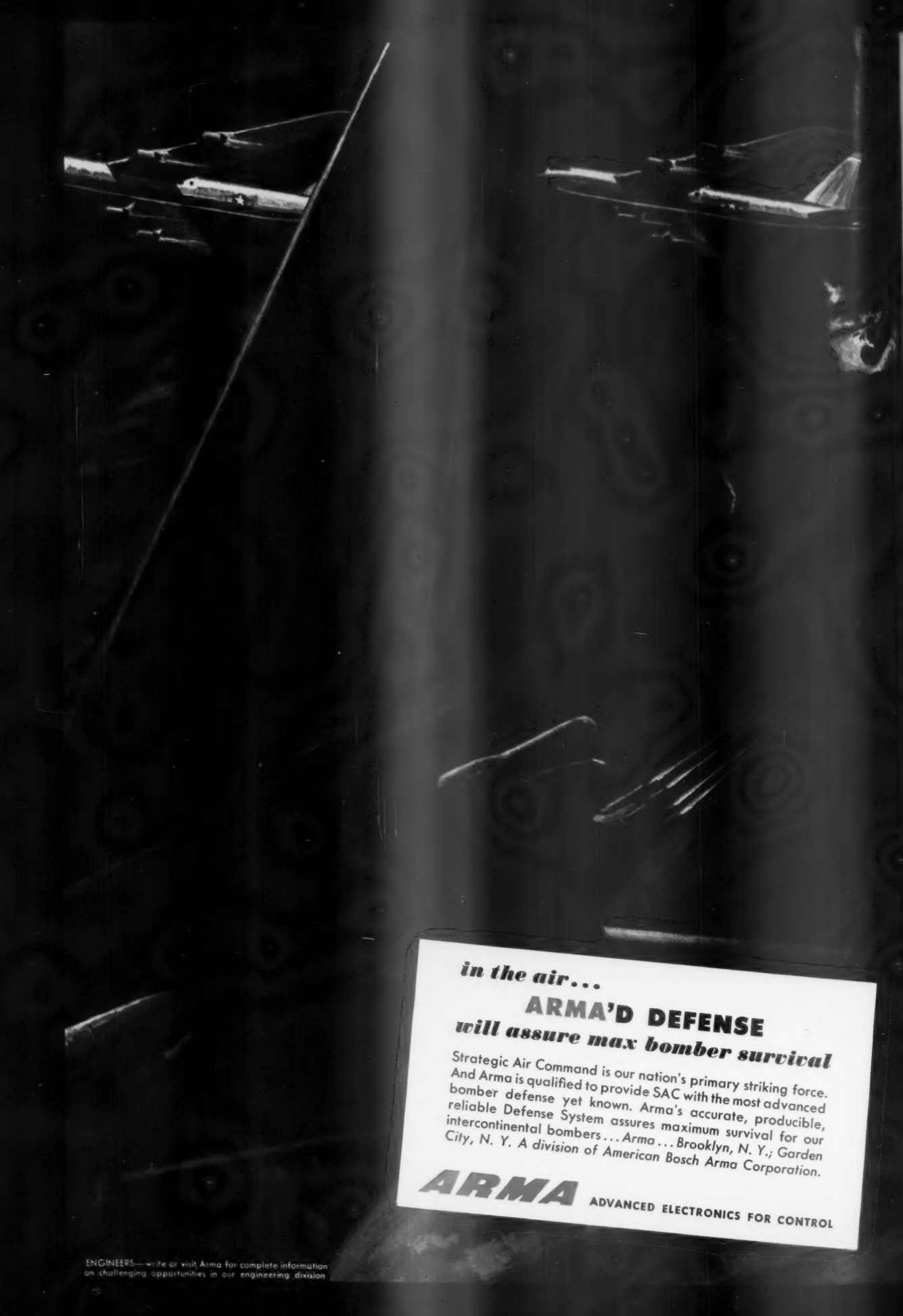
Aeronautical Engineering REVIEW

April, 1955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Aeronautical Engineering Review

Vol. 14—No. 4 April, 1955

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Cover—First photo of the Lockheed Hercules (YC-130) prototype in flight shows the Air Force transport on a test run in Southern California. Besides carrying troops, supplies, or wounded men, the huge plane (wing span 132 ft., length 95 ft.) is designed to drop paratroops or paracargo over enemy territory. Lockheed claims the YC-130, which is now in production at Marietta, Ga., can use relatively short or rough runways and can fly higher and faster than present military transports. The four Allison T-56 turboprop engines together develop 15,000 hp.

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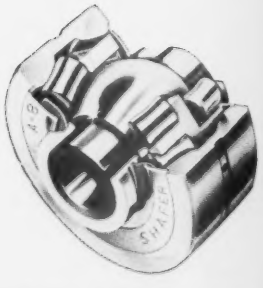

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I.A.S. News Notes

April 1955

INSTITUTE COMPILING TELEMETERING PROCEEDINGS

A record of the papers presented at this year's jointly-sponsored Telemetering Conference in Chicago, May 18-20, will be published and distributed by the IAS. It is anticipated that this volume will contain approximately 266 pages and that it will be available at the Conference. Copies may also be obtained from the IAS in New York at $3.50.

A limited number of the 1954 and 1953 Proceedings are still available at $2.00 per copy.

* * * * * *

IAS COSPONSORS FALL CONFERENCES AT PURDUE UNIVERSITY

Two Midwestern Conferences, one on Fluid Mechanics and the other on Solid Mechanics, are scheduled for September 8-10, at West Lafayette, Ind. Complete details will follow in an early issue of the Review.

* * * * * *

NEW IAS CORPORATE MEMBERS

Aerophysics Development Corporation, P.O. Box 657, Pacific Palisades, Calif.
Avro Aircraft Limited, Malton, Ontario, Canada.
Nuclear Development Associates, Inc., 80 Grand Street, White Plains, N.Y.

* * * * * *

NATIONAL MEETINGS CALENDAR

June 20-23 Fifth International Aeronautical Conference, IAS Building, 7660 Beverly Blvd., Los Angeles, Calif.
Aug. 8-10 Turbine-Powered Air Transportation Meeting, Seattle, Wash.

* * * * * *

CALENDAR OF SECTION MEETINGS

Apr. 5 - Los Angeles Section: Field Trip to Bethlehem Steel Corporation, Vernon, California, 8:00 p.m.

Apr. 8 - Washington Section: Tour of Glenn L. Martin plant. "Modern Airplane Production Methods" by Boyd K. Bucey, Boeing Airplane Co.

Apr. 11 - Los Angeles Section: IAS Building. Special Meeting, 8:00 p.m. "Solved and Unsolved Problems in Aerodynamics" by Dr. Theodore von Karman, Director, AGARD.

Apr. 12 - Los Angeles Section: IAS Building. Specialist Meeting, 8:00 p.m. "Design Considerations for Turboprop-Powered Cargo Aircraft" by Winfield H. Arata, Jr., Lockheed Aircraft Corporation.

Apr. 13 - Atlanta Section: Atlanta Athletic Club. President's Night. Social

CALENDAR OF SECTION MEETINGS (CON'T.)

Hour, 6:30 p.m.; Dinner, 7:00 p.m. Speech by Robert E. Gross, IAS President and President, Lockheed Aircraft Corporation.

Apr. 13- Niagara Frontier Section: Crosby-Brounshidle Post. Meeting, 8:00 p.m. "Techniques of Model Testing in Free Flight" by Joseph A. Shortal, Chief, PARD, Langley Laboratory, NACA.

Apr. 14- Baltimore Section: Flight Refueling, Inc. Dinner, 5:30 p.m.; Plant Tour, 6:30 p.m.; Meeting, 7:30 p.m. "Technical Developments of In-Flight Refueling Systems" by Theodore R. Farrington, WADC, and "Carrier-Based Refueling Operations" by Capt. N. Gaylor, USN.

Apr. 16- Hampton Roads Section: Inspection and demonstration at Fort Eustis (Va.) Heliport, 8:30 a.m. to 12:00 noon.

Apr. 16- Seattle Section: Tour of Air Defense Command, McChord AFB, Wash., 10:30 a.m. to 2:30 p.m. Talk on "Air Defense Command" by Brig. Gen. Romulus W. Puryear.

Apr. 18- Boston Section: M.I.T. Meeting, 8:00 p.m. "Preliminary Airplane Design as Practiced in the Research Division of the Bureau of Aeronautics" by Abraham Hyatt, Director, Research Div., BuAer.

Apr. 20- Chicago Section: Meeting, 7:30 p.m. "Air Force Logistics and Decentralization" by Major Gen. Fred R. Dent, Jr.

Apr. 21- Los Angeles Section: IAS Building. Social Hour, 6:00 p.m.; Dinner, 7:00 p.m.; Meeting, 8:15 p.m. Lecture on Guided Missiles by R. E. Gibson, Director, Applied Physics Laboratory, Johns Hopkins.

Apr. 23- Los Angeles Section: IAS Building. Annual Spring Dance, 9:15 p.m.

Apr. 23- San Diego Section: IAS Building. Spring Dance, 9:00 p.m.

Apr. 28- Dayton Section: Miami Hotel. Dinner, 6:30 p.m.; Meeting, 8:00 p.m. "Arctic Flight Operations" by Col. Bernt Balchen, Special Assistant for Arctic Activities, USAF Headquarters.

Apr. 28- Twin Cities Section: The White House, Minneapolis. Social, 6:00 p.m.; Dinner, 7:00 p.m.; Meeting, 8:00 p.m. "Aircraft Structural Problems Due to Aerodynamic Heating" by Nicholas J. Hoff, Polytechnic Institute of Brooklyn.

May 3- Los Angeles Section: Field Trip to Pasadena Air Filter Center, Air Force Ground Observer Corps, 8:00 p.m.

May 10- Los Angeles Section: IAS Building. Specialist Meeting, 8:00 p.m. "Analytic Prediction of Missile Guidance Accuracy" by Warren E. Mathews, Senior Staff Physicist, Hughes Aircraft Company.

May 11- Niagara Frontier Section: Airways Hotel, Buffalo Airport. Meeting, 7:30 p.m. "Island Hopping in the Antilles" by R. M. Stanley.

May 19- Los Angeles Section: IAS Building. Social Hour, 6:00 p.m.; Dinner, 7:00 p.m.; Meeting, 8:15 p.m. "Acceptance Testing of Naval Aircraft" by Capt. L. S. Chambers, USN, Board of Inspection and Survey, NATC, Patuxent River, Maryland.

May 24- Los Angeles Section: IAS Building. Specialist Meeting, 8:00 p.m. "Predicting Transition in Incompressible Flow" by A. M. O. Smith, Supervisor, Aerodynamic Research, El Segundo Division, Douglas.

* * * * * *

IAS News

A Record of People and Events of Interest to Institute Members

Tentative Programs for Electronic Conferences in Dayton and Chicago

IAS One of Two Cosponsors of Dayton Meeting and One of Four Cooperating Societies at Chicago Meeting. Hugh L. Dryden Dinner Speaker at Chicago Meeting.

THE INSTITUTE OF THE AERONAUTICAL SCIENCES is cooperating with the Institute of Radio Engineers in the sponsorship of the 1955 National Conference on Aeronautical Electronics in Dayton, Ohio, May 9–11. Later that same month, May 18–20, the IRE and IAS join with the American Institute of Electrical Engineers and the Instrument Society of America in presenting the 1955 National Telemetering Conference at the Hotel Morrison in Chicago.

A forum on the subject "Weapons Systems Concept and Its Effect on Aeronautical Electronics" is being planned for the afternoon of the tenth at the Dayton meeting. It will be moderated by Ivan Getting, Vice-President, Raytheon Manufacturing Company. Among those who are scheduled to participate in this forum are Major Gen. C. S. Irvine, USAF Deputy Chief for Production; August Eisenwein, Vice-President and General Manager, Convair-Fort Worth Division of General Dynamics Corporation; and W. R. Persons, President, Emerson Electric Manufacturing Company.

Also planned for the 1955 National Conference on Aeronautical Electronics are 22 technical sessions. The program for the Dayton conference, as it shapes up at press time, is outlined below. The figure enclosed in parentheses after each session listing is the number of papers to be delivered at that particular session.

▶ **Monday, May 9**—*Morning sessions:* Semiconductors I—Transistors and Rectifiers (5); Antennas and Propagation I (6); Management I—Engineering and Production (6); and Electronic Components I (5). *Afternoon sessions:* Semiconductors II—Circuits (6); Antennas and Propagation II (6); Reliability (6); and Measurement and Test I (6).

▶ **Tuesday, May 10**—*Morning sessions:* Ferromagnetics and Plastics (5); Human Engineering (6); Computers (5); and Servomechanisms (4). *Afternoon sessions:* Forum (see above); Radio Interference (6); and Environmental Conditions (4).

▶ **Wednesday, May 11**—*Morning sessions:* Electron Tubes I (5); Equipment (6); Navigation I (6); and Measurement and Test II (6). *Afternoon sessions:* Electron Tubes II (5); Information Theory (6); Navigation II (6); and Circuits (5).

The foregoing sessions will be held either at the Biltmore Hotel or the Engineers Club, Dayton. It was announced at press time that J. D. Ryder, IRE President, is to be one of the luncheon speakers and that Louis M. Hull, Chairman, Board of Directors, Aircraft Radio Corporation, is this year's winner of the Pioneer Award.

At the 1955 National Telemetering Conference in Chicago, Hugh L. Dryden, Director, NACA, will speak at the dinner on Thursday, May 19, on the subject "Problems in Ultra High Speed Flight." The Friday luncheon speaker is to be William A. Wildhack, Chief, Office of Basic Instrumentation, National Bureau of Standards, whose topic will be "In-Accurate Transmission of Mis-Information."

Hugh L. Dryden

A total of eight technical sessions have been planned for the Chicago meeting. These sessions and their chairmen are tentatively scheduled as follows:

▶ **Wednesday, May 18**—*Morning session:* Components I—Industrial Telemetering, K. C. Black; *Afternoon sessions:* Systems I—Industrial Telemetering, P. A. Borden; and Components II—Pick-Ups and Transducers, K. M. Uglow.

▶ **Thursday, May 19**—*Morning session:* Systems II—Flight Testing, C. A. Taylor. *Afternoon sessions:* Systems III—Multiplexing Techniques, E. L. Gruenberg; and Components III—New Developments in Telemetry and Remote Control, J. T. Mengel.

▶ **Friday, May 20**—*Morning session:* Systems IV—New Developments in Telemetry and Remote Control, W. J. Mayo-Wells. *Afternoon session:* Components IV—Data Processing, C. F. West.

The proceedings for last year's National Telemetering Conference is now available at $2.00 a copy. Anyone interested in obtaining a copy of the 1954 proceedings may write to the IAS Publications Department, 2 E. 64th St., New York 21.

Chance Vought, an IAS Corporate Member

Chance Vought Aircraft, Incorporated, a Corporate Member of the Institute of the Aeronautical Sciences, was founded in 1917 by Chance Milton Vought and Birdseye Lewis. The company, now located in Dallas, Tex., had its beginnings in Long Island City, N.Y. Its first airplane was the VE-7, a trainer designed and built for the Army Air Corps.

Since 1919, however, the company's history has closely paralleled the history of Naval aviation. From the day that Chance Vought VE-9's went aboard the first U.S. aircraft carrier, the U.S.S. "Langley," there has never been a time when Vought airplanes were not on active duty with the Navy.

Chance Vought, as a division of United Aircraft Corporation for many years, was located at Hartford and Stratford, Conn., successively, before moving to Dallas in 1948. On July 1, 1954, the company became a completely separate and independent manufacturer of jet aircraft and guided missiles.

Chance Vought currently is producing the F7U-3 Cutlass Navy fighter and the Regulus guided missile. The Cutlass is a general purpose, transonic, carrier-based fighter equipped with twin J46 turbojet engines. It is classed in the "more-than-650-miles-an-hour" category.

Regulus is a surface-to-surface missile in quantity production for the Navy. Developed jointly by Chance Vought and the Bureau of Aeronautics, it operates from submarines, surface vessels, and shore bases.

Test and training versions of Regulus are equipped with landing gear to permit recovery. Test missiles, as a result, have been flown and landed repeatedly, one as many as 15 times. They offer an economical method of gathering test data and of training Navy personnel.

Chance Vought also is engaged in the development of a new high-performance Navy day fighter, the XF8U-1. The company won a design competition with this airplane in 1953. Further details are being withheld by the Navy until it is in operation.

Brooklyn Polytechnic's Conference on High-Speed Aeronautics

A Conference on High-Speed Aeronautics, sponsored by the Polytechnic Institute of Brooklyn, was held in New York January 20–22. The meeting included an opening session, four technical sessions (three on aerodynamics and one on structures), the official opening of the school's Freeport Laboratory, and a banquet at which Ralph S. Damon, President, Trans World Airlines, Inc., was the speaker.

Preston R. Bassett, Chairman of the Corporation, Brooklyn Polytechnic, was the Chairman of the session that opened the 3-day conference. The welcoming address was given by Dr. Harry S. Rogers, President of Brooklyn Polytechnic. The keynote address on "Solved and Unsolved Problems in High-Speed Aerodynamics" was delivered by Dr. Theodore von Kármán, Chairman, Advisory Group for Aeronautical Research and Development, NATO, Paris, France.

The four technical sessions were held on the afternoon of January 20, the morning and afternoon of the twenty-first, and the morning of the final day. The official opening of the school's Freeport Laboratory and its inspection on the afternoon of January 22 brought the 3-day conference to a conclusion.

The Proceedings of the Conference on High-Speed Aeronautics is being published by the Brooklyn Polytechnic. For information on the proceedings, please contact Dr. Nicholas J. Hoff, Head, Department of Aeronautical Engineering and Applied Mechanics, Polytechnic Institute of Brooklyn, 85 Livingston St., Brooklyn 2, N.Y.

New York's Safety Convention and Exposition

The Twenty-Fifth Annual Safety Convention and Exposition will be held April 11–15 at the Hotel Statler in New York. This Silver Jubilee meeting is being sponsored by the Greater New York Safety Council with the cooperation of 71 national and local agencies. The Institute of the Aeronautical Sciences is numbered among the 71 cooperating agencies.

During the course of this 5-day safety convention, more than 200 speakers will deliver papers at 58 sessions. The sessions will cover nearly all fields of industrial, home, highway, and school safety. The speakers are to include Government officials, educators, law-enforcement authorities, administrators, industrial and civic leaders, and members of the engineering and medical professions.

The exposition, held in conjunction with the sessions, will feature some 150

The photo at the left shows Capt. J. Laurence Pritchard (*right*), Member of the Council, Royal Aeronautical Society, presenting an illuminated scroll of felicitations on behalf of the RAeS to Dr. Harry S. Rogers, President of the Polytechnic Institute of Brooklyn. In the right-hand photo, Dr. Rogers greets Dr. Theodore von Kármán (*left*), Chairman, Advisory Group for Aeronautical Research and Development, NATO. Looking on are Preston R. Bassett, Chairman of the Corporation, Polytechnic Institute of Brooklyn (*second from left*) and Dr. Nicholas J. Hoff, Professor and Head of the school's Department of Aeronautical Engineering and Applied Mechanics.

displays of the latest in safety equipment, devices, and accident-prevention aids and tests. The exposition will be open to the public from April 11 through 15. The Silver Jubilee convention dinner will be on the fourteenth of the month.

Automatic Control Courses

The University of Michigan, College of Engineering, has announced two Intensive Courses in Automatic Control. The first of these is scheduled for June 13–18, and the second one will meet June 20–22, 1955.

The two courses are built around the principles and application of measurement, communication, and control. Course I will consist of the fundamentals in each of these fields and will include some fundamental work in nonlinear systems. Course II will take up applications of the fundamentals to more advanced problems. There will be 4 hours of lectures each morning and 3 hours of laboratory demonstration in the afternoon. Extensive use will be made of computing, instrumentation, and servo laboratories on the campus. The role of analog computing methods will be emphasized.

Closing date for registration is April 15. For further information, please write to Professor L. L. Rauch, Room 1521, East Engineering Building, University of Michigan, Ann Arbor, Mich.

The von Baumhauer Medal, the obverse and reverse of which are shown here, is given by the Royal Netherlands Aero Club "to the person who in a given period of 3 years has made the most valuable contribution either in a scientific or a practical sense to flight safety." A portrait of the late Albert von Baumhauer is on the medal's obverse; the inscription on the reverse is translated "consumed in the service of others." This medal was established in 1939; however, wartime conditions precluded its being presented until this last December 9 when it was awarded to Jerome Lederer, FIAS, Managing Director, Flight Safety Foundation, Inc. Mr. Lederer, whose name is etched into the side of the medal, received it for his contributions to flight safety in the 1951–1954 period.

Necrology

George P. Hodgson III

George Pannill Hodgson III, TMIAS, Flight Test Engineer, The Glenn L. Martin Company, was killed in an airplane crash on November 22. He was 28 years old.

A native of Richmond, Va., Mr. Hodgson attended Fluvanna County High School, Carysbrook, Va., from 1940 to 1944. He entered Virginia Polytechnic Institute in 1947 and was graduated from there in June of 1951 with a B.S. degree in Aeronautical Engineering.

He went to work for Martin the month following his graduation from V.P.I. He was first an Engineering Trainee, learning the Martin company's method of drafting and lofting, and later was made a Senior Draftsman. He had been a Flight Test Engineer for about 2 years.

News of Members

▸ **Major General Victor E. Bertrandias,** USAF (AM), retired from the Air Force on February 28. General Bertrandias was Deputy Inspector General and thus headed up the USAF's flight safety program.

▸ **Jack Frye** (F) resigned, effective April 1, 1955, as President and as a Director of General Aniline & Film Corporation. Mr. Frye intends to devote his attention to a new aviation development along with other interests.

▸ **Felix Kallis** (AF), Senior Research Engineer, Rocket Engine Field Laboratory, North American Aviation, Inc., was given the Civilian Meritorious Service Award by the Navy Department for his outstanding performance of duty at the U.S. Naval Air Station, San Diego, prior to joining North American. Mr. Kallis, formerly Jet Power Plant Engineering Supervisor, Overhaul and Repair Department, San Diego NAS, received this award last spring.

▸ **John K. Northrop** (F), Founder and former President of Northrop Aircraft, Inc., was elected a member of the Board of Directors of The Garrett Corporation. Mr. Northrop is an IAS Past-President.

▸ **Dr. Theodore von Kármán** (HF), Chairman, Advisory Group for Aeronautical Research and Development, NATO, has resigned the Chairmanship of the USAF Scientific Advisory Board in order to devote his full time to AGARD. Dr. von Kármán has accepted the honorary position of Chairman Emeritus of the SAB, a post tendered to him by the Air Force in recognition of his contribution to aeronautical science. He had been SAB Chairman since 1944.

▸ **Charles Clement Walker** (HF) retired from the Board of Directors, The de Havilland Aircraft Company, Ltd., at the close of business on December 31, 1954. He is continuing in his day-by-day service to the de Havilland company. Mr. Walker is also an Honorary Fellow of the Royal Aeronautical Society.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of IAS members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.

Krishin P. Abichandani (M), Aerophysics Engineer, Lear Incorporated, Grand Rapids, Mich. Formerly, Design Engineer, Air Armament Section, Electronics Division, Canadian Westinghouse.

R. Harvey Anselm (M), with Guided Missile Division, Beech Aircraft Corporation. Formerly, Administrative Director, Field Test Engineering Division, Holloman Air Development Center, Radioplane Company.

(*Continued on page 72*)

Guest Editorial

The Partnership of Science and the Air Force*

"The necessity for an effective partnership between our scientific and military communities is a well-accepted feature of our professional lives. Such a partnership has long been the rule within the Institute of the Aeronautical Sciences, where the relationship has held since the birth of the society, and wherein there is such a wide representation of military men. . . .

"The strong scientific community in this country has found that it must devote a substantial portion of itself to maintaining military superiority. We face not only the task of maintaining current technical strength and of improving it for the years that lie immediately ahead but also the less clearly defined job of assuring technical military superiority for the more distant future. A substantial part of this last responsibility, that of maintaining military strength for the future, lies directly in the hands of the science partner of the science-military partnership.

"Today's situation clearly differs from another within our ken, that at the beginning of World War II. Before that war, only a small percentage of science and engineering was devoted to military affairs. When it became apparent that our country must mobilize, science was mobilized along with industry and the military. Scientific research and the fundamental training of scientists and engineering students were almost completely stopped. . . .

"Today and tomorrow such a complete mobilization of science would be undesirable. If war occurred, we would not have time to make our work felt. If war did not occur and we had mobilized our science, we would be neglecting our basic education and science. A continuous partial mobilization of science is required. This puts the scientific community in a difficult position, for it must, on the one hand, achieve the proper, delicate balance of effort among education, basic research, and nonmilitary development, and, on the other hand, participate in building our military strength. . .

"On the military side of our activity, the contacts of our engineering and scientific community with the Air Force take a great variety of forms. By far the greatest contact comes in our relationship as contractors to the Air Force for research and development. In this activity, whether it is as an individual with a small-scale research program or as a member of a large development team with a complicated weapon system program, we must do our enthusiastic best in the job we are doing. We all recognize that enthusiasm for the job and conviction of the importance of the result are as important contributory elements to success as good technical ability and adequate physical facilities. The system of contracting for research and development must be flexible to take full advantage of the widely differing attacks on research problems and the variety of approaches to weapon systems development.

* Excerpts from a Luncheon Speech, Twenty-Third Annual Meeting, IAS, New York, January 24–27, 1955.

By

H. GUYFORD STEVER

Chief Scientist, United States Air Force

This freedom for some individual direction of the program in research and development in looking for technical gains and technological "breakthroughs" is comparable to that granted to front-line tactical battle commanders in probing and capitalizing on the weakness of the enemy's position.

"A diversity of program is particularly important today when we are in such a radical transition phase in the development of technical weapons. Such problems as that of complete automatism versus human skills in aircraft flight, and winged bombers versus ballistic missiles, are still open to considerable debate. The transition period is marked by many differing weapon system possibilities as yet unevaluated. These can be evaluated finally only after more research and development exploitation. The transitional nature of technical weapons is reflected in operational commands, which today often contain an interesting admixture of the old and the new. . . .

"A system of governmental and military support, which gives some of this desired diversity of approach which we want in research and development, poses, however, a different problem to which the scientific community must address itself. As research and development programs become more clearly defined in their applicability to military weapons, the demands for technical man power, facilities and equipment, and financial support for each of these developments grow at an ever-increasing rate. In these commodities we are seriously limited. The price we pay for some flexibility at one end of the research and development scale, therefore, is the additional difficulty we have in the selection and phasing of the important programs into new weapons at the other end of the scale. The responsibility of decision in this matter of selection of the lines of major emphasis for military weapons is largely with our military partners, but we also share their job. To prepare them to make such decisions, we must offer our best technical assistance. Furthermore, together, we and they must ensure that maximum effective use is made of our assistance. We cannot afford to take our best technical minds completely off teaching, research, and development tasks to make them full-time participants in this job of selection of the most fruitful lines for weapons development. Yet our military partners must get at least part of our time together with our full acceptance of the importance of these selections to our long-term technical strength. . . .

"This problem of bringing to the military forces the full power of the scientific and engineering community to assist in mapping the technical future of the Air Force is a vital one that we must meet and solve. Further, it must be done without upsetting the balance of effort on the other primary jobs of our technical community—that is, education, research, development, and production engineering."

The Air Research and Development Team

LT. GEN. THOMAS S. POWER, USAF

Commander

Air Research and Development Command

THE TOPIC "The Air Research and Development Team" is a most timely one because never before in history has it been more important for industry, science, and the Armed Forces to work together as a team.

We won the last war by quantitative superiority. But we must face the fact that, in any future war, we cannot match the combined resources of the Iron Curtain countries. Man for man, tank for tank, plane for plane, we are outnumbered.

And, if we try to counter quantity with quantity, we shall strain our man power and resources to the point where we could easily ruin economically what we are trying to protect militarily.

Thus, our only alternative is to achieve and maintain qualitative superiority. And by "qualitative superiority" I do not mean complex gadgets and scientific miracles but practical weapon systems that are both highly advanced and suitable for use in the field. As Paul V. Galvin, of Motorola, put it so aptly: ". . . We have spent far too much time designing equipment for engineers rather than for military applications. We have produced laboratory wonders which have been manufacturing headaches and military flops. . . ."

During my 27 years of service, most of which has been with combat units, I have become acutely aware of the relationship between the man and his equipment when measuring combat potential—which is, after all, what we are all trying to develop.

I know that the most courageous crews, no matter how superbly trained, cannot hope to compete successfully against an enemy possessing vastly superior equipment and armament. It is our job, and by that I mean all of us, to see that American crews are never placed in this position. We must maintain qualitative superiority.

To achieve and maintain such qualitative superiority for the United States Air Force is the sole mission for which the Air Research and Development Command was organized as a separate, major air command in January, 1950. We realize we cannot possibly accomplish that mission except through close teamwork with science, industry, and our sister commands.

As aeronautical engineers, many of you have had occasion to work with one or more segments of ARDC, but you may not know that during 1953, for example, 87 per cent of our research and development money went to some 160 universities, colleges, and other nonprofit institutions and to 1,520 industrial companies.

Indeed, you are playing a most important part in the defense of this nation!

Other members of our team are the Air Materiel Command, which is responsible for the procurement and maintenance of the air weapons we develop, and the operating commands that, ultimately, use them.

Needless to say, we also enjoy the fullest cooperation of many agencies of the Army and Navy and other Government organizations such as the National Advisory Committee for Aeronautics and the Bureau of Standards.

This team play is mandatory from the very outset of a new project because the ever-growing complexity of our weapon systems requires the most careful planning and closest cooperation in order effectively to turn a dream into a piece of practical hardware. We have to phase in new weapon systems at the proper intervals.

On the one hand, we have to make thorough preparation for their introduction into combat units, or the

Presented at the January 13, 1955, meeting of the IAS Baltimore Section.

results can sometimes be a loss of combat capability rather than the gain we all seek.

On the other hand, we must move as fast as we can to capitalize on new systems and components which promise dramatic gains in combat capability. And, all of the time we have to be careful not to break the bank by trying to hold on to and improve all of our old capabilities while generating many new ones. All of us know how important this balance is and, sometimes, how difficult it is to achieve.

Now, you have heard a great deal about weapon systems. While the weapon system concept, as such, is not new, we have established a weapon system discipline for that part of our work which can and must be subjected to controls of time schedules and operational performance requirements. These are stern controls, and we intend to enforce them.

At the same time, we intend to make sure, in our support of research and state-of-the-art development, that there shall be considerable freedom from scheduling controls. This is necessary to ensure that future weapon systems, when they are laid down, may be built around the best components and techniques which American science and technology are capable of bringing forth.

Under the procedure through which we implement the weapon system concept, Headquarters USAF initiates a directive for a new system needed to meet a military requirement. The detailed plan for carrying out the directive is a joint effort between ARDC and industry. This plan is carefully coordinated with the combat commander concerned and with the commander of the AMC. It is approved by Headquarters USAF.

The phasing-in of the different components to meet time and budgetary limitations is studied in Headquarters ARDC, and a directive is issued to one or more of our ten Centers outlining their respective responsibilities in regard to timing, priorities, budget, etc. One of the Centers is designated to be responsible for coordination.

The decision to produce in quantity for inventory is, of course, made in Headquarters USAF. The point in the development cycle at which this decision is made is subject to many considerations. As a rule, if time is not absolutely vital, we recommend delaying the start of production until the actual testing of hardware has demonstrated the chances of success or failure of the weapon system as a whole.

Such decisions to start or hold back production on any weapon system require sound military judgment, arrived at through the coordinated thinking of the Defense Department, Headquarters USAF, ARDC, AMC, and the combat commander.

The main reason effective weapon system management has become such a critical problem is the revolutionary change that has been brought about by nuclear weapons, particularly hydrogen bombs. In the event of general war, we would undoubtedly do the decisive fighting with what we have when the first bombs start dropping.

This means that practically all of our relatively limited Armed Forces must be able to go into action immediately. Obviously, if we saddle the combat units with the development job and take away their old but usable equipment to substitute it with new but nonoperational equipment, we shall seriously cripple their combat potential.

Notwithstanding the admitted importance of military research and development, funds for the purpose have always been limited, except in a few instances. This situation is certainly not less true today than it has been during the past couple of years. Further, I hazard the guess that such funds will not be more abundant in the near future, unless, of course, there should be some radical changes in the international situation.

The weapon systems that are most vital to the Air Force are extremely expensive, and in many areas the cost will continue to rise. It seems, therefore, to be clearly in the cards that we will, in the years ahead, be reducing the number of models and new weapon systems in development and production.

In trying to get more combat potential per dollar, we look to our contractors for help. More than ever before, there is a need for the continued development of new manufacturing methods and techniques which will materially reduce the cost of aircraft and aeronautical equipment.

I am confident much can be achieved along these lines because it is in this very field that American science and industry have proved to be the unchallenged masters. There is another thing our contractors can do to help all of us, and that is to present realistic time and cost figures in submitting proposals. This gets to be more and more important as the complexity of systems increases. The proper phasing of a multitude of different components is mandatory in meeting established time and fund limitations.

Since assuming command of ARDC, I have had occasion to visit a large segment of the aircraft, engine, and component industry throughout the United States. Of necessity, these visits were brief, but they enabled me to obtain an impression of the "personality" of the organizations I visited—if I may use the term "personality."

Some organizations seemed to place the emphasis on production, while others appeared to place it on research and development. Quite naturally, I was especially interested in their research and development organization, particularly their long-range thinking.

In this connection, I believe there will be interest in my analysis of a fundamental change that has been taking place during the last year. As is known, the basic strategic philosophy that this country used to employ was what may be called a "mobilization concept." We maintained in peacetime only a small military force, designed to keep training doctrines alive and prepared to hold the line until the great civilian population could shift from civilian activities to join and make up our military effort.

From a hardware point of view, it was primarily a production job because we did not have the time for research and development of new weapon systems. Granted there was product improvement and some highly concentrated research, but, I repeat, it was primarily a production job.

Now, when the war was over, it was customary to disband the military force and convert industry back to the production of civilian goods. Also, the highly concentrated research groups went back to their colleges and universities. As I mentioned before, the atom and hydrogen bombs have changed all this, and we now must rely on our force-in-being.

Today, we have a large military force that has become a part of our normal way of life. But the significant point is that a large military production has also become a part of our normal life. However, we can no longer give industry a weapon system and say, "Produce it!" Instead, industry must now research and develop it under highly competitive conditions.

A good number of our big and little companies that went out of the military hardware business after World War II have now come back into it as a continuing company policy. This means that they all are maintaining large research and development staffs. The Air Force's responsibility for managing and coordinating this tremendous scientific effort has placed a burden upon the ARDC.

It has been most gratifying to me to learn during the previously mentioned visits and in my many discussions with representatives of scientific and industrial organizations that they consider national defense their concern as well as the military's and that they are willing and anxious to accept commensurate obligations and responsibilities.

But I also found occasional lack of understanding of the peculiar problems that the military organizations face. It must be realized that, in many respects, a military organization such as the Air Force is not different from any other large business and must be administered and operated accordingly. Our stockholders, the American people, expect us to make their huge investment pay dividends—in our case, lasting air supremacy. Our stockholders also expect us to meet competition successfully by always being a jump ahead of our "competitors" on the other side of the Iron Curtain. And they expect us to do all this within the budget and man-power limitations they have established!

This business type of operation is particularly evident in the ARDC. Our headquarters in Baltimore is organized along the lines of an industrial organization. We have a Deputy Commander—or you might call him a vice-president—for Technical Operations and a Deputy Commander—or vice-president—for Support Operations. The former is responsible for all aspects of the Command research, development, and test programs, while the latter is responsible for providing and managing resources and services.

This type of organization offers two primary advantages, one external and one internal. First, it facilitates our job of managing the research and development team composed of science, industry, and ourselves; second, it permits us to direct effectively our own team—the ten research, development, and testing Centers that make up the ARDC.

During the last year, we have established a number of new management tools, and I shall briefly outline some of the more important ones.

First of all, we have published Air Force Regulation 70–9, which defines Air Force policy on weapon systems development and procurement. This was intended to assure the continued health and balance of our supporting industry. In addition, this regulation enables the Air Force to obtain technical aid for its systems engineering effort.

Next, we have published a long-needed revision of Air Force Regulation 20–10. This regulation, which outlines Air Force policy in the weapon systems area and delineates responsibilities for its implementation, now establishes an important new concept called "primary executive management responsibility."

This, briefly, means that, at any stage of development and production of a weapon system, either ARDC or AMC—but never both—will be assigned the executive responsibility. While each Command must use the functional services of the other in discharging this responsibility, there can be no more doubt as to where the overall responsibility lies at any particular stage. And, as soon as the management responsibility is transferred from ARDC to AMC, the latter assumes the chairmanships of the Weapon Systems Project Offices and of the supporting Phasing Groups.

This system is now working smoothly and efficiently. One major reason for its success is the fact that General Rawlings, the Commander of the Air Materiel Command, and I, as well as our top staffs, now meet regularly once a month to establish the guiding policies and ground rules for the joint efforts of ARDC and AMC in the management of weapon systems.

To enhance further the close cooperation between the two Commands and to keep it in line with established Air Force policies, General Rawlings and I also meet regularly with Mr. Lewis and Mr. Gardner, of the Secretary's office, and with Generals Boatner and Putt, the Deputy Chiefs of Staff for Materiel and Development, respectively.

But the improvement of our relationship with AMC was not our only concern. It was equally important to work with the other Air Force commands toward a better mutual understanding.

To this end, we have initiated a program that, from time to time, features a "Strategic Air Command Day," a "Tactical Air Command Day," an "Air Defense Command Day," etc., which take place at the Wright Air Development Center. On such a day, the commander of the featured command and his top staff are briefed on the latest advances and developments per-

(*Continued on page 47*)

Aerodynamic Design of a High-Altitude Rocket

A. W. PEPPERS*
The Glenn L. Martin Company

THE VIKING SINGLE-STAGE ROCKET SERIES—designated RTV-N-12a—was developed by The Glenn L. Martin Company, in the postwar period, for the Naval Research Laboratory's high-altitude investigations. Specifically, these rockets were designed for research at altitudes between 100 and 200 miles.

Experimental equipment was provided for the measurement of pressures, temperatures, densities, cosmic rays, ionization, and other stratospheric conditions and phenomena. The Vikings also carried cameras to measure the intensity of daylight sky illumination, to obtain photographs of large areas of the earth's surface, and to collect rocket aspect data.

Basic information obtained from these experiments is of practical benefit in radio communication, meteorology, and guided-missile design. The Vikings have proved to be useful tools not only in the furtherance of man's knowledge of the upper atmosphere but in the advancement of the understanding of the mechanics of rocket flight.

The basic aerodynamic configuration of a typical Viking, as shown in Fig. 1, consists of a cone-tipped cylinder. The maximum diameter is 45 in., and the rocket is approximately 42 ft. long. Static aerodynamic stability is provided by four symmetrical, double-wedge, delta plan-form fins, containing 22 sq. ft. of area per plane. The fins are placed 90° apart at the afterend of the body.

Control and stability in the roll axis are obtained by tabs and small peroxide jets located at the tips of the fins. Control and stability in the pitch and yaw axes are obtained by movement of the thrust cylinder, which is mounted in gimbals.

The power plant is a Reaction Motors, Inc., XLR10-RM-2 liquid oxygen and alcohol rocket engine, producing 21,000 lbs. of thrust at sea level.

Such pioneer rocket designs as the V-2, the WAC Corporal, and the early Vikings—RTV-N-12—employed thrust-to-weight ratios in the neighborhood of 2. Viking No. 8, one of the RTV-N-12a configuration, was the first rocket design in which this ratio was reduced—to increase its altitude capability. Analysis of T/W ratios of 1.15, 1.4, and 2.0 had indicated that these values would make possible altitudes of approximately 213, 155, and 125 miles, respectively. Although the lowest thrust-to-weight ratio makes possible the highest altitude, it also results in the lowest take-off acceleration—with attendant stabilization and safety problems.

As a practical compromise, a thrust-to-weight ratio of 1.4 was selected for this Viking.

The rocket develops 21,000 lbs. thrust, which sets the take-off gross weight at 15,000 lbs. Basically, this weight is divided as follows: 2,000 lbs. dry weight, 1,000 lbs. pay load, 6,500 lbs. oxygen, and 5,500 lbs. alcohol. The propellant load gives a burning time of approximately 105 sec.—enough to reach an altitude in the neighborhood of 150 miles. Reduction of pay load by 500 lbs. would allow an altitude of approximately 200 miles. The Viking attains a maximum velocity of 6,000–7,000 ft. per sec. (Fig. 2), and a Mach Number of from 5 to 6 at its burnout altitude—170,000 to 200,000 ft.

Coincident with this performance, maximum drag, in the neighborhood of 4,500 lbs., is attained in the transonic region (see Fig. 3). Peak dynamic pressure—of approximately 690 lbs. per sq.ft.—occurs 56 sec. after take-off, or at an altitude of about 40,000 ft. Maximum acceleration at the end of powered flight is about 6g.

One of the first decisions to be made in any rocket design concerns the general contour of the body. Here the designer not only must keep a watchful eye on aerodynamic problems but also must consider structural, component, fabrication, and accessibility factors. The final selection is a compromise, representing all of these.

For the Viking, structural and fabrication studies indicated the value of a simple cone-ogival nose and straight cylindrical body. Also, it was found that no severe structural penalties would result from ratios of length to diameter as high as 18 to 1. Supersonic wind-tunnel tests indicated that, for a given volume, the drag varies little with length-to-diameter values between 11 and 18.

In choosing the rocket diameter, consideration was given to engine diameter, volumetric efficiency of components, ease of fabrication, and accessibility. On this basis, then, a diameter of 45 in. was selected and—to obtain the necessary pay load and propellant volume—the missile had to be 495 in. long. This gave a length-to-diameter ratio of 11, which is within the desired range.

Once again, fabrication and mounting requirements, as well as aerodynamic factors, must be considered in the design of the missile's nose. Of all the possible shapes, perhaps the best known is the simple cone. A conical nose is relatively easy to manufacture to aerodynamic tolerances and is excellent, also, from the drag viewpoint.

Drag decreases with decreasing nose apex angle, but volume requirements dictate limits to the angle's size. Thus, for the Viking, an included angle of 25°

* Senior Aerodynamics Engineer.

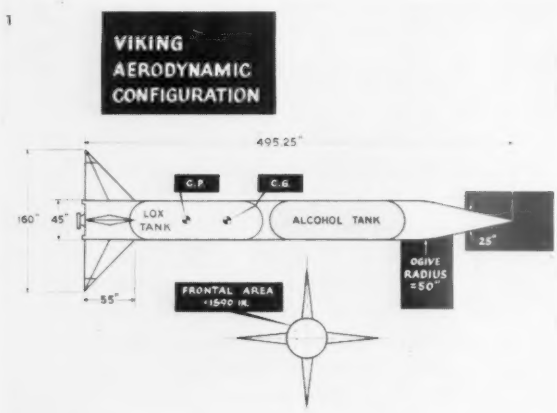


FIG. 1. Aerodynamic configuration.

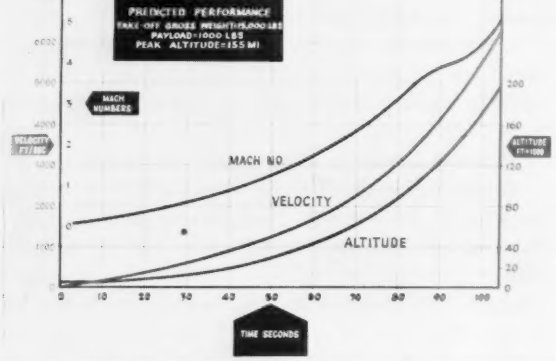


FIG. 2. RTV-N-12a Viking. Predicted performance: Mach Number, velocity, and altitude versus time.

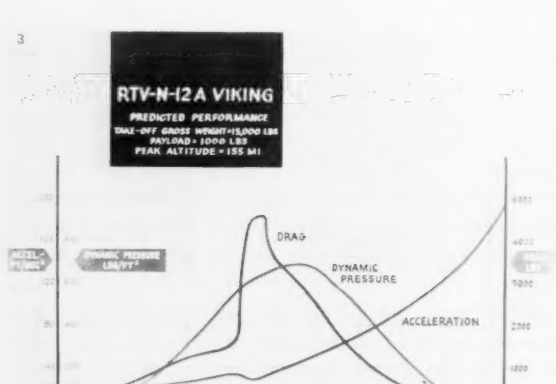


FIG. 3. RTV-N-12a Viking. Predicted performance: Drag, dynamic pressure, and acceleration versus time.

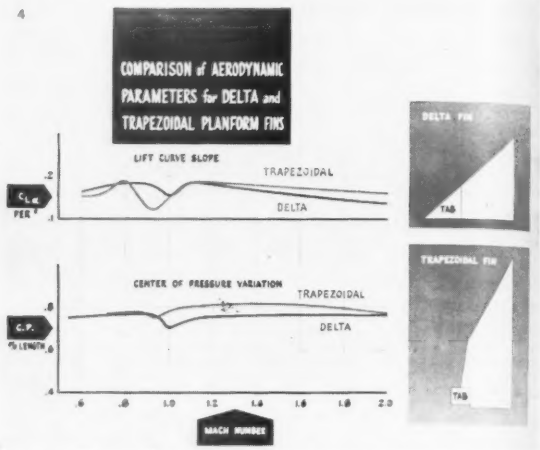


FIG. 4. Comparison of aerodynamic parameters for delta and trapezoidal plan-form fins.

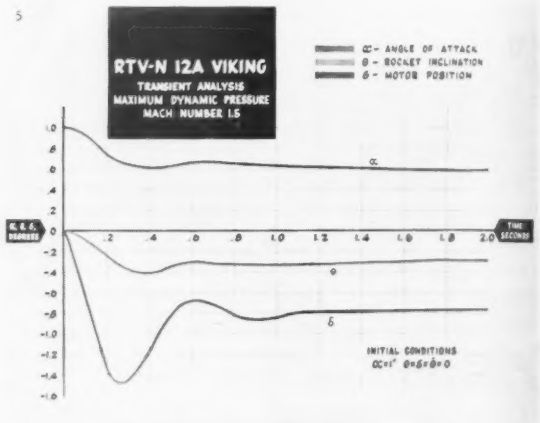


FIG. 5. Transient analysis: Angle of attack, rocket inclination, and motor position versus time.

FIG. 6 Viking flight trajectory.

was selected as a compromise between drag and volume.

After determination of the body configuration, it was necessary to decide whether aerodynamic surfaces were needed to maintain the rocket's stability. Studies involving the Viking's control system indicated that fins were, in fact, needed. It is not desirable to have a margin of stability which is too high or too low. If the distance between the center of gravity and center of pressure is great, large moments will be required from the control system to overcome a heading into the wind—a weathercock tendency. If the margin is too low, the rocket will depend primarily on artificial means—the control system—to maintain stability. Thus, the problem resolves itself into finding the fin configuration that will give a favorable center of pressure location.

For the Viking, a stability margin of one body diameter appeared to be suitable for holding the rocket on its desired flight path with the control system used. This margin was also adopted in the design of the German V-2. A large variety of fin shapes will provide this stability. Wind-tunnel tests, however, indicate the superiority of a double-wedge, delta planform fin.

The delta plan form has a high lift-to-drag ratio, due to the high aspect ratios made possible by its structural rigidity. This high lift-to-drag ratio means that a smaller surface may be used for an equal stability, and the smaller surface, of course, has less drag. Structural rigidity also makes possible low thickness ratios without prohibitive weight, and both considerations are important to rocket performance.

One of the best features of the delta plan form is the small variation of aerodynamic parameters with Mach Number. As can be seen in Fig. 4, the center of pressure movement and the lift curve slope have an insignificant change in value in the supersonic region, when compared to a trapezoidal plan-form fin. The prime significance of this is small variation in required control moments.

The delta plan form also permits the use of an aerodynamically balanced, all-movable tip tab control, which reduces operating loads and removes blanketing problems associated with partially submerged control surfaces. Since the double-wedge cross section is made up entirely of plane surfaces, it satisfies aerodynamic criteria and is relatively simple to manufacture.

Determination of the fin and body configuration leaves the aerodynamicist in a position to determine the rocket's pitch-yaw and roll stability. Because the rocket is geometrically identical in the pitch and yaw planes, it is necessary to consider only the pitch plane.

Pitch stability transfer functions may be calculated by the well-known equations of motion. Since the values of these equations vary throughout flight because of changes in the aerodynamic parameters and atmospheric properties, it is necessary to evaluate transfer functions at several places throughout the flight. It should be pointed out that, even though the rocket is statically stable, the flight path will tend to diverge because of the action of gravity.

The summation of forces perpendicular to the flight path, plus the moments about the center of gravity, can readily be obtained for any point along the trajectory. Combination of these equations—plus the control law for the gimballed motor—can then be set up on an analog computer and responses to various disturbances determined. In stability calculations, primary emphasis is placed on determination of the time involved for the rocket to return to its original heading after a displacement.

The Viking's in-flight stability is usually calculated at a moderate subsonic Mach Number, at the Mach Number corresponding to maximum dynamic pressure, and at a supersonic Mach Number. The behavior of the missile at maximum dynamic pressure—corresponding to Mach Number 1.5—is shown in Fig. 5. An initial angle of attack of 1°—corresponding to a sudden cross-wind gust of 25 m.p.h.—is damped to one-half amplitude in approximately 9 sec.

Furthermore, the rocket's heading remains at small amplitude, and the motor uses, at most, one-third of its allowable travel. Thus it can be concluded that no serious divergence from the intended flight path would occur if the missile were suddenly to encounter a 3° angle of attack—the maximum to be anticipated, according to existing data.

Roll control for the Viking is provided by four 20-lb. thrust jet motors and two tabs—on two of the four tail fins. The jets, which use hydrogen peroxide to produce their energy, prevent rolling just after launch and before cutoff. During these intervals, the fins have an insignificant aerodynamic effect due to the low initial velocity after launch and the low density near burnout.

The tab size was predicated on the specification that the rocket roll no more than 5°, with transients of 15° allowable. Once again, tab transfer functions may be placed on an analog computer. Roll responses to a disturbance are calculated to determine whether such roll control requirements can be met by the tab configuration and roll control system.

The trajectory of a Viking-type rocket may be divided into three parts: powered flight, coasting flight, and re-entry into the atmosphere (Fig. 6). The equations for powered flight may be solved by means of a step-by-step integration. Figs. 7 and 8 show a comparison of actual and predicted performance of Viking No. 10, using these equations. As can be seen, the predictions were accurate for that rocket's flight.

Coasting flight performance is based on the rocket's flying a ballistic trajectory in a vacuum, and it is during this important period that the Viking performs its data-collecting mission. Although the re-entry portion of the flight has an effect on the range, this is primarily determined by the conditions at cutoff.

Thus far, we have dealt with the major aerodynamic considerations involved in designing a rocket. Many other problems must be considered in integrating the

FIG. 7. Viking No. 10. Performance: Actual and predicted drag, dynamic pressure, and acceleration versus time.

design. One such problem is evaluation of the effects of Coriolis force on the rocket's trajectory. This force causes a Viking to veer westward from its course by about 8 miles. To correct for Coriolis—so that its impact occurs at the center of the range—the rocket is fired 3° east of North.

In addition, the aerodynamicist must supply air loads to the structures engineer. He must furnish information on tab operating loads and missile dynamics to the controls designer. He must supply pressure orifice locations to the instrumentation engineer. The fairing design must be communicated to the drafting team, and antenna locations must be worked out with the electronics department. Furthermore, close liaison must be maintained with the manufacturing department to see that aerodynamic tolerances are met. All of these problems must be solved before the rocket is flight fired.

What aerodynamic problems exist after the rocket is fired? All flights of an experimental rocket, such as the Viking, must be carefully analyzed to determine whether the preflight theoretical and test work has been sound. Any in-flight errors must be explained and corrective action taken before the next rocket is fired.

To analyze the rocket's trajectory, the angle of attack, rocket inclination, and flight-path angle must be determined. Knowing any two of the above, the third can be calculated. Rocket inclination and angle of attack can be determined by air-borne instruments, whereas the flight-path angle can be found from velocity data provided by radar, doppler, or optical equipment. However, measurements by more than one instrument sometimes produce conflicting results—and the aerodynamicist must sort out the correct answers.

Since the Viking is designed for a flight-path angle closely approaching the vertical, all trajectory and attitude angles are small. For example, a normal flight-path angle is of the order of 4°, rocket inclination is of the order of 3.5°, and angle of attack is of the order of 0.5°. From these orders of magnitude it can be seen that extremely accurate information is needed.

An angle of attack error of 0.2° can make a 40 per cent change in force balance. Similarly, an error of 0.5° in the rocket's attitude will give an error of 100 per cent in the angle of attack. Although the present instrumentation is sufficient for solving Viking problems, more precise attitude and flight-path data would be invaluable to the designers of ballistic weapons.

The previous discussion has been concerned with present aerodynamic problems. But what of the future? What advancement lies ahead for the Viking?

A conical nose was selected, because of the large amount of aerodynamic data that had been collected on this shape, because of its low drag, and because it is easy to manufacture to aerodynamic tolerances. If the present nose were modified, however, its volume could be increased. A truncated cone with a hemispherical tip has been suggested. With proper design of tip radius and semiapex angle, the effect of drag on this nose would be the same as, or less than, that of the present cone.

What about pressure? At present, volumes of work could be done on both base pressures and body pressures.

One of the most important characteristics of a Viking-type missile is the base drag. Unfortunately, it is not readily calculable and is extremely complicated because of the action of the jet. The most likely answer to base pressure questions would appear to be available through increased instrumentation during the rocket's flight. It would be desirable not only to determine the average magnitude of base drag but also to determine base pressure profiles so as to better our understanding of the airflow about the base.

A structurally lighter Viking might be possible, if more precise data were available on body pressures. A parachute recovery system—enabling the rescue of major components and the carrying of tape recorders and other instruments—also presumes the need for accurate pressure information to determine parachute and shock loads. Once again, it must be pointed out that body pressures are not readily calculable.

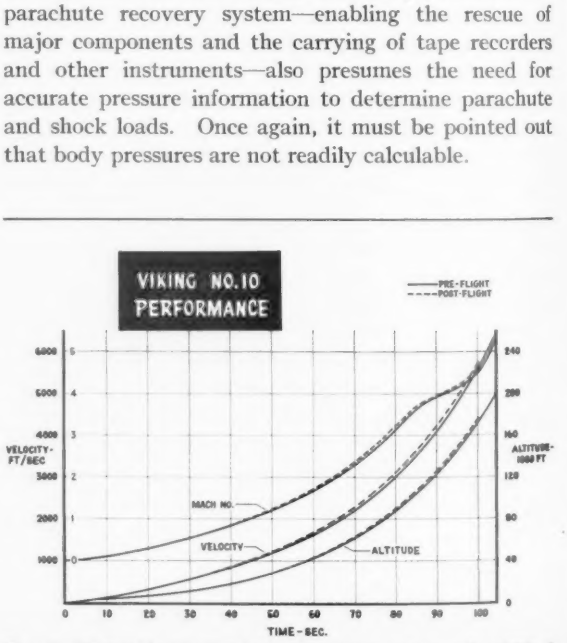


FIG. 8. Viking No. 10. Performance: Actual and predicted Mach Number, velocity, and altitude versus time.

A parachute system, moreover, demands answers to other air load, shock load, drag, and rocket-motion questions. These answers will not be forthcoming until the re-entry portion of rocket flight can be more fully examined.

The boundary layer, aerodynamic heating, and re-entry are all relatively unexplored areas. The advancement of future rockets will depend to some extent upon the understanding of these three important considerations. Work on the boundary layer has been going on for a number of years. More must be known of the boundary layer's characteristics—its thickness, velocity gradients, pressure gradients, and heat-transfer coefficients—before means can be employed to control its effect on friction drag and body heating.

Present knowledge is limited concerning the effects of aerodynamic heating—often referred to as the "heat barrier." From the aerodynamics viewpoint, it would be desirable to determine the heating effects on the aerodynamic parameters, particularly on friction drag.

Aerodynamic heating may also be carried through the structure, affecting the operation of electronic and other equipment. In the case of a manned rocket, it may endanger personnel. This heating problem must, therefore, be correctly evaluated, so that the rocket's personnel and equipment can be suitably protected.

Most aerodynamic heating theories appear to be inadequate in their present form for practical applications. More research on this subject must be done before rocket design can be advanced, and before more ambitious engineering projects can be undertaken.

The re-entry problem has been dramatically associated with the moon rockets. From the aerodynamic point of view, however, this problem consists of the evaluation of range dispersal, recovery of stability, and heating of the body—as it travels through the air at hypersonic speeds. Present wind tunnels cannot deliver the needed velocities. They are limited by scale effects, temperature, and size. Consequently, with present equipment, one of the best ways to obtain re-entry data is by actual flight use of the high-altitude rocket.

In conclusion, the intent of this paper has been to point out a few of the aerodynamic problems encountered and solved successfully in the design of the Viking. From this background, some future problems—and their effect on the design of the high-altitude rocket—can be seen. The achievement of the goal of manned flight into space will follow when the capabilities of upper air research vehicles, like the Viking, have been extended by further development and flight testing.

The Air Research and Development Team

(*Continued from page 42*)

taining to their particular mission. They, in turn, are given an opportunity to present to our staffs their own thoughts and criticisms.

We are also planning a "Science Day" to which we intend to invite high ranking representatives of science and industry to inform them of our problems and to stimulate their interest in helping us solve them. And, twice a year, each of our Centers is scheduled to be host to one of the panels of the Air Force's Scientific Advisory Board for a thorough briefing on projects of particular concern to the members of the respective panels.

Finally, we have endeavored to coordinate closely the efforts of all activities within our own Command. For instance, we have initiated monthly conferences of the ARDC Center Commanders—with a different Center acting as host each month—in order to foster closer relationships among the Centers and provide regular opportunities to discuss our mutual problems.

In conclusion, I should like to re-emphasize that the Air Research and Development Command will continue to strive for still closer cooperation with its partners on the national defense team. That will be the firm policy and objective of ARDC and myself.

I am confident that, as a result, this country will maintain the leading position in today's technological race—The Sliderule War!

Let us hope that through such a posture of strength we can maintain the peace, uneasy as it is.

Members Please Note:

Have you returned your Roster Card?

(See page 58 of this issue.)

Titanium Fastener Progress

ANDREW N. ESHMAN*
Mallory-Sharon Titanium Corporation

AIRCRAFT DESIGN STANDARDS ENGINEERS have awaited the production of aircraft quality titanium fasteners for some time. Where the use of titanium sheet in many instances requires that the part be redesigned or a new design made, titanium fasteners constitute a direct substitution. Fasteners amount to a sizable portion of the gross weight of an aircraft. Savings ranging from a few hundred to over a thousand pounds can be obtained on various types of aircraft.

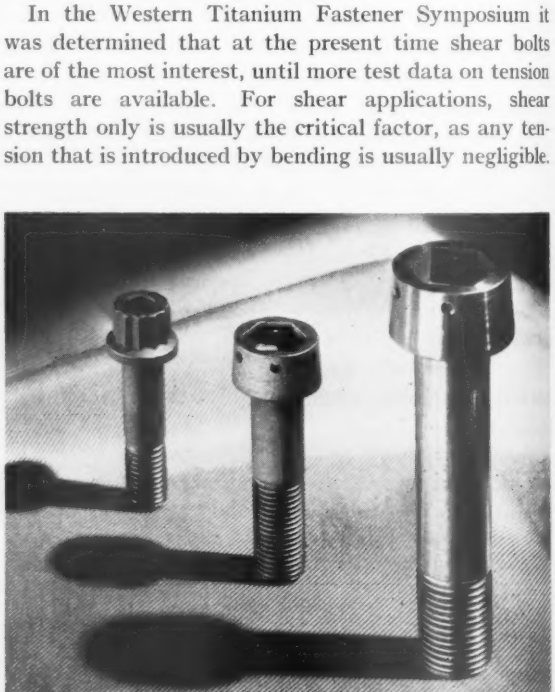
In the beginning, the titanium fastener development was plagued by the same growing pains that affected titanium in all fields. Choice fabrication methods were not resolved, and available raw materials in bar and rod left much to be desired by the fastener producers. Consequently, many test reports on titanium fasteners showed conflicting results. However, the good results indicated that tremendous possibilities existed when good material was combined with proper fabricating procedures. In addition to advancement in fabrication techniques and availability of far superior materials, metallurgists and research engineers now more fully understand the nature of titanium as an engineering material. As a consequence, cautions that need to be exercised in design and in fabrication can be recommended.

Fastener materials that are currently being specified are the alpha-beta type of alloys. To the metallurgist this means that the material at room temperature and up to a transition point is composed of two types of crystalline structure. The alpha portion is hexagonal close packed, while the beta is body centered cubic. For example, iron has a body-centered cubic lattice, while magnesium has a hexagonal close-packed structure. Thus, at room temperature, titanium has a combination of the same type of lattice possessed by iron and magnesium. When an alpha-beta material is heated sufficiently high and long enough to a temperature close to the transition point, the alpha will transform into beta. For all practical purposes the type of structure of titanium is of little interest to the fastener fabricator or user, and yet the amount of each phase has a tremendous bearing on both fabrication and usage. Because of this, a brief and general review of the mechanism of heating and forming titanium would seem in order.

Alloying elements such as in our present fastener materials, like manganese, chromium, and vanadium, stabilize the body-centered cubic beta phase—that is, this phase is present in varying amounts at room temperature depending on the per cent alloy addition. Elements such as aluminum stabilize the alpha phase and permit higher working temperatures where both alpha and beta are present by pushing the beta transus upward. In upsetting a fastener head, the best combination of properties such as good strength, ductility, and toughness can be obtained by working the material in the alpha-beta field. In all metals that transform from one solid crystalline form to another, transformation takes place at a certain temperature and in a certain length of time. In induction heating that is properly accomplished for hot upsetting, the time cycles are usually short, somewhere on the order of a few seconds. Consequently, complete transition of the alpha phase to the beta phase does not have sufficient time to take place, although the heating temperature may be close to the beta transus or transition temperature. As a result, the fastener is worked in the alpha-beta field, and the large unstable beta grains are not formed.

In early fabrication of fasteners, although the material was induction heated, abnormally high temperatures were used, and all of the work took place in the beta field. Fasteners fabricated in this manner usually possessed extremely brittle characteristics with the failures occurring in the large grain size heads rather than in the threads. In addition to fabrication problems, often the raw material had seams that opened into cracks when the blanks were headed.

In the Western Titanium Fastener Symposium it was determined that at the present time shear bolts are of the most interest, until more test data on tension bolts are available. For shear applications, shear strength only is usually the critical factor, as any tension that is introduced by bending is usually negligible.



Typical titanium fasteners.

* Service Engineer.

The relationship of shear to ultimate strength is shown in Fig. 1 for MST 3 Al-5 Cr. Shear tests to date on this alloy indicate that, with a known ultimate strength, shear strength is predictable with 95 per cent confidence to within ±5,600 lbs. per sq.in. Shear strengths of titanium alloys currently being used are listed in Fig. 2.

For fasteners used in tension applications many considerations other than yield and ultimate strength are necessary. Fatigue, stress rupture, and relaxation all enter into the picture. Because of the complexities involved in tension bolt requirements, more careful consideration must be given to the choice of a particular material. As in steel, in many instances higher ultimate strengths do not always answer when the application involved concerns fatigue.

In tension bolts, fatigue in many cases is a critical factor. This is probably true today more than ever in the past as modern aircraft are being designed more in terms of service life and loading. Also, with today's structural materials, there has been a steady reduction in design-safety margins with more parts and components loaded closer to the minimum strength of the material.

Fatigue results on titanium have varied considerably. Usually a reason for these variations is found and can be controlled.

Material variations, design, and fabrication all have contributed in varying amounts to the low-cycle fatigue failures. In a proposed military specification on titanium shear bolts, the thread root radius for $^{3}/_{16}$- and $^{1}/_{4}$-in. bolts is 0.003 and 0.004 in. respectively. If such a thread root radius were used on a tension bolt, fatigue results similar to those shown in Fig. 3 would be expected.

In the comparison of fatigue properties shown in Fig. 3 both alloys were tested on rotating beam fatigue machines. Stress concentration factors were 4.0 for the 4 Al-4 Mn alloy and 4.75 for the 6 Al-4 V alloy. Probably if a notch radius of 0.005 in. were used on the 6 Al-4 V material, the endurance limit would be approximately 50,000 to 60,000 lbs. per sq.in. Only limited tests on a few heats have been made on this particular material, but the results are encouraging. In addition to the notch fatigue tests, notch tensile tests were run. The test results indicated that the as-rolled or as-annealed tensile strength of 150,000 lbs. per sq.in. was increased to 220,000 by the presence of a sharp notch. Both the notch fatigue tests and the notch tensile tests indicate that this alloy is much less notch sensitive than any titanium material we have had available this far. The notch fatigue properties of the 6 Al-4 V are superior not only to other titanium alloys but to the notch fatigue properties of various alloy steels commonly used for fasteners.

Material variations from heat to heat probably have accounted for much scatter in fatigue tests. This has been caused in part by segregation of the various alloying elements within a particular heat as well as by segregation and an excess of interstitials such as carbon, oxygen, nitrogen, and hydrogen. We do not know at

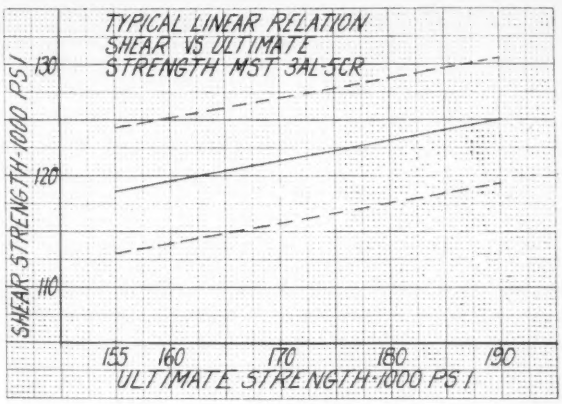


FIG. 1.

SHEAR AND ULTIMATE STRENGTHS OF TITANIUM FASTENER MATERIALS

MATERIAL *	ULTIMATE STRENGTH-PSI	SHEAR STRENGTH-PSI
MST 3AL-5CR	160,000	120,000
MST 4AL-4MN	155,000	105,000
MST 6AL-4V	150,000	112,000
MST 3MN COMPLEX	165,000	111,000

* AS ROLLED AND STRAIGHTENED

FIG. 2.

NOTCHED FATIGUE PROPERTIES OF TITANIUM FASTENER MATERIALS

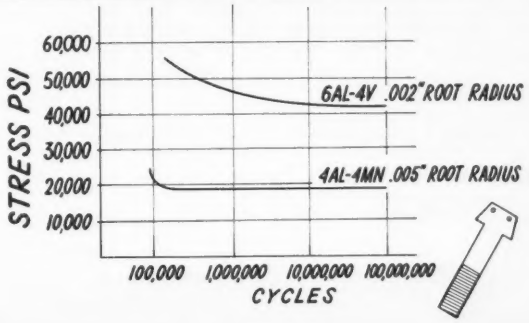


FIG. 3.

COST COMPARISON OF TITANIUM VS. STEEL AN-509 AIRCRAFT SCREWS

SCREW SIZE	WEIGHT/1000 SCREWS		WEIGHT SAVED	COST PER POUND OF WEIGHT SAVED
	TITANIUM	STEEL		
	POUNDS	POUNDS	POUNDS	DOLLARS *
5/16-21	15.96	28.00	12.04	44.15
6/16-20	23.94	42.00	18.06	46.91
7/16-20	31.35	55.00	23.65	38.23

* BASED ON 5000 PC LOTS

FIG. 4.

present the absolute minimum or maximum levels of the gaseous elements which can be tolerated without adversely affecting properties. However, as in steel, when these interstitial elements can be kept low, fatigue improves accordingly. For some time at Mallory-Sharon, all of our materials have been double melted using a consumable electrode process. This type of melting improves ingot homogeneity and thereby lessens both alloy and interstitial segregation. To summarize the fatigue results, it would appear that when homogeneous material is properly fabricated into a well-designed fastener, the fatigue properties will be consistent and equal or better than those of the conventional alloy steels of today.

In all titanium fastener applications eventually the difficulties will be resolved. Similarly, the cost of titanium will be lowered by increased production and better melting and fabrication methods. However, our main interest now is in current fastener performance and cost. In several leading technical and aviation magazines, costs of various types of fasteners have appeared. Usually the prices quoted have meant only *one*. The same fastener in lots of 1,000 or 5,000 might have been $^1/_3$ or less than that of the price quoted. In connection with the economic angle, one aircraft company made an analysis of the cost of identical steel and titanium bolts in 5,000-piece lots. The results are shown in Fig. 4. Judging from these data, the use of titanium fasteners in this type and size would cost between $40 and $50 for each pound of weight saved. How much 1 lb. of weight saved is worth in an aircraft depends entirely upon the type of aircraft, application, and stage of design or production. However, figures have been offered with a spread of $20 to $200 per lb.

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The Problem of Routing Aircraft

A Mathematical Solution

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The RAND Corporation

MATHEMATICAL TECHNIQUES for the solution of many practical economic and operational problems have been developed extremely rapidly in recent years, stimulated in large part by the demands that World War II made upon military planners. A major portion of these new techniques, having basically similar mathematical characteristics, is called linear programming. Some types of transportation problems have been subjected to this kind of analysis over a period of several years,‡ and useful results have been obtained.

The purpose of the present paper is twofold: (1) to present and explain a method for assigning a given fleet of several different types of aircraft to carry an anticipated traffic load over several routes at minimum cost and (2) to illustrate the application of linear programing to transportation problems of this general type.

The problem that has been chosen, while simpler than the routing problem faced by an air line, is reasonably realistic. Much more complicated problems can be handled with basically the same techniques. However, they would not serve the present illustrative purposes.

The following problem has been chosen: A fixed fleet of four types of airplanes are to carry passengers over five routes. The objective is to develop a route pattern for the fleet which minimizes the cost of performing the transportation demanded, considering lost revenue as equivalent to a cost.

Four types of airplanes have been used: Type A, representing a postwar four-engined airplane; Type B, a postwar two-engined airplane; Type C, a prewar two-engined airplane; and Type D, a prewar four-engined design. Variable costs per hour and per landing-take-off cycle have been roughly estimated to reflect the differences in out-of-pocket operating costs for the types of aircraft used.

The various types are assumed to operate at different speeds and to carry different loads on any given route. It is also assumed that certain types of aircraft cannot—because of range limitations—operate on particular routes, and, further, that some types of aircraft cannot carry their full pay load on certain other routes.** To introduce a further element of heterogeneity into the problem it is assumed that the utilization obtained by each airplane type varies from route to route. On the two transcontinental routes 300 hours per month per airplane are assumed to be obtainable; on the Dallas route, 285; and on the Boston route, 240.

In this way we have set up a problem that, we hope, incorporates enough of the actual problems of routing to be interesting and one whose optimal solution is not obvious by inspection, while preserving enough simplicity to permit solution without large computing machines.

The assumed traffic demand and characteristics of the fleet and routes are shown in Tables 1, 2a, and 2b.

To recapitulate, the problem is to employ in an optimal fashion a fleet of 69 aircraft of four types to carry a total of 124,000 passengers per month over five routes.

The solution is accomplished in a simple mechanical fashion, which, in this case, involves four approximations and the final solution. Each approximation embodies the following steps. A blank table is set up showing initially only the fleet of aircraft, the routes, and the passenger demand (in hundreds) on each route as given in Table 1. Then, using Table 2, aircraft are

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† Mathematics Division.

‡ See references at end of paper for information regarding theory and application of linear programing.

TABLE 1
Assumed Aircraft Fleet and Traffic

Aircraft on Hand		Traffic Load			
Type	Number		Route	Number of Passengers*	Route Miles†
A	10	(1)	N.Y.–L.A. (1 stop)	25,000	2,475
B	19	(2)	N.Y.–L.A. (2 stops)	12,000	2,475
C	25	(3)	N.Y.–Dallas (0 stop)	18,000	1,381
D	15	(4)	N.Y.–Dallas (1 stop)	9,000	1,439
		(5)	N.Y.–Boston (0 stop)	60,000	185

* The anticipated number of full one-way trips per month to be carried on each route. If a passenger gets off en route and is replaced by another passenger, it is counted as one full trip.

† *Official Airline Guide*, July, 1954, p. 276. The N.Y.–Los Angeles routes are via Chicago and via Chicago and Denver; the stop en route between New York and Dallas is at Memphis.

** Specifically, it is assumed that Type C cannot fly either Route 1 or Route 3, and Type B cannot fly Route 1. Also, Type B is assumed to operate at 75 per cent of full pay-load capacity on Route 3, and Type D is assumed to operate at 80 per cent of full pay-load capacity on Route 1.

TABLE 2a
Assumed Variable Costs per Passenger-Mile (Units = $0.001)

Aircraft Type	New York–Los Angeles, 1 Stop	New York–Los Angeles, 2 Stops	New York–Dallas, 0 Stop	New York–Dallas, 1 Stop	New York–Boston, 0 Stop
A	4.5	5.7	4.5	4.7	6.4
B	...	6.4	8.3	6.3	8.8
C	...	9.2	...	9.3	11.3
D	7.4	6.1	5.9	6.2	8.1

TABLE 2b
Assumed Variable Costs and Passenger Capabilities per Aircraft per Month

Aircraft Type		New York–Los Angeles, 1 Stop	New York–Los Angeles, 2 Stops	New York–Dallas, 0 Stop	New York–Dallas, 1 Stop	New York–Boston, 0 Stop
A	Passengers (00)	16	15	28	23	81
	Costs ($000)	18	21	18	16	10
B	Passengers (00)	..	10	14	15	57
	Costs ($000)		15	16	14	9
C	Passengers (00)	..	5	..	7	29
	Costs ($000)		10		9	6
D	Passengers (00)	9	11	22	17	55
	Costs ($000)	17	16	17	15	10

assigned to each route until either all aircraft in the fleet are employed or all passengers wishing to travel are served. Then (as will be explained below) the system is "costed" in implicit values or "shadow prices" and examined for situations in which a shift of aircraft between routes would reduce the costs. This process is repeated until no further opportunities for economizing remain. The resulting set of values can be proved to be optimal.

To illustrate in detail: Table 1 shows the demand on each route and the aircraft available to satisfy that demand. Table 2a shows which aircraft are most economical on each route. It will be noted that Type A is most economical in cost per passenger-mile on all routes. Hence, it was decided to allocate this type first. Also, since they are a long-range airplane, they were assigned first to Route 1 (Table 3). The ten Type A's would, under our assumptions, carry less than the 25,000 passengers per month anticipated for that route. Hence, more aircraft are assigned—namely, enough Type D's (the only other airplane assumed capable of flying the route) to carry the remaining passengers. Table 3 thus shows ten A's and ten D's assigned to the New York–Los Angeles one-stop route.

Moving to Route 2, Type D is found to be the most economical of the three types still not entirely committed (Table 2a). Therefore, the remaining five are assigned to that route, and the remaining passengers are to be carried in Type B's—the more economical of the two types still available. Thus Table 3 shows 6.5 B's and 5 D's on the New York–Los Angeles two-stop route. Aircraft assignments (such as 6.5 B's) need not come out in whole numbers since, for example, 0.5 B is to be interpreted as assigning one aircraft to the route for half a month, say, on alternate days.

Turning to Route 3, there are no A's or D's left for assignment, and the C is, by assumption, not capable of flying the route. Therefore, the remaining 12.5 Type B's are assigned to Route 3, and they accommodate all but 500 of the 18,000 passengers desiring to fly the route.

Only Type C's remain. Of these, 12.8 are assigned to Route 4, and this is adequate for the 9,000 passengers per month demanding travel on the route. The remaining 12.2 of that type are available for Route 5, but since they are incapable of carrying all the New York–Boston traffic, 24,600 passengers per month are left unserved.

Note that the entire fleet of 69 aircraft are committed and that, except on the New York–Boston run, the passenger demand is essentially filled. Further, although airplanes have been assigned in a simple and somewhat arbitrary fashion, the assignment is not obviously absurd. The longest range aircraft are assigned to the longest haul, the New York–Los Angeles routes. The routes with the shortest critical legs have only Type C's. The New York–Los Angeles two-stop and the New York–Dallas nonstop routes, with substantially equal critical legs, have middle-range Type C's and, on Route 2, D's.

Now the question is whether this is the best solution. If in any case costs of the whole system can be reduced by shifting aircraft between routes the solution is not optimal. To determine whether this is the case, the first tentative solution must be "priced out," and each of the activities to which no aircraft are assigned must be checked to determine whether its introduction into the solution would result in any economies.

The procedure for determining whether a particular set of activities is optimal may, upon first reading, seem rather complex, but it can be done quickly by inspection for a small problem such as the one under consideration.

The process can best be explained by reference to Table 4a. Each cell has three entries (zeros are represented by blanks). In the upper left corner of each cell is the number of aircraft assigned to the activity (from Table 3); in the center is the number of passengers (in hundreds) which one airplane of each type can carry on that route (from Table 2b). In the bottom row is the monthly variable cost (in thousands of dollars) per aircraft assigned to the route (Table 2b). Thus the upper left cell indicates that ten Type A's will be allotted to Route 1 and that each will carry 1,600 passengers per month at a (variable) cost of $18,000. It will be convenient to denote the three entries in any row (i), and in any column (j), by the following symbols:

X_{ij} = number of aircraft
p_{ij} = passengers (00)/month/aircraft
c_{ij} = cost ($000)/month/aircraft

The variable cost of performing each activity, c_{ij}, is arbitrarily divided into two sets of implicit values, which may be construed to be the cost per airplane, u_i, column (7), and the cost per passenger, v_j, row (6). The u_i's may be considered as the implicit opportunity cost of operating the ith aircraft on any route and the v_j's the cost of transporting a passenger on the jth route

TABLE 3
First Approximation

Aircraft Type	New York–Los Angeles, 1 Stop	New York–Los Angeles, 2 Stops	New York–Dallas, 0 Stop	New York–Dallas, 1 Stop	New York–Boston, 0 Stop
A	10				
B		6.5	12.5		
C				12.8	12.2
D	10	5			
Deficit passengers (00)			5		246

by any airplane. The determination of the assigned values of the v's and u's follows certain simple rules. In the first place, the u_5's corresponding to surplus aircraft, column (7), are always 0. All other u_i's are determined through the equations $u_i + p_{ij}v_j = c_{ij}$ where only those (i, j) combinations are used which appear in that particular assignment of aircraft which is being costed. From Table 3 or 4, the permissible combinations are (1, 1), (4, 1), (2, 2), (4, 2), (2, 3), (5, 3), (3, 4), (3, 5), and (5, 5). Hence, $u_5 + p_{55}v_5 = c_{55}$ may be written

$$0 + v_5 = 1$$
$$v_5 = 1$$

In a similar fashion, v_3 may be found to equal 7. Since there is only one cell in column (5) to which aircraft are assigned and since the value of v_5 has been determined, it is possible simply to ascertain the value of u_3,

$$u_3 = c_{35} - p_{35}v_5$$

or

$$u_3 = 6 - 29 \cdot 1 = -23$$

Knowing u_3, it is possible to obtain the value of v_4 by solving for it with the data in cell (3, 4). In a similar manner, it is possible to determine the implicit costs ("shadow prices") in each cell.*

For the particular approximation shown in Table 4a, the values of the u's and v's, as shown in column (7) and row (6), are:

$u_1 = -174$	$v_1 = 12$
$u_2 = -82$	$v_2 = 9.7$
$u_3 = -23$	$v_3 = 7$
$u_4 = -91$	$v_4 = 4.6$
$u_5 = 0$	$v_5 = 1$
	$v_6 = 0$

Using these values it is possible to determine whether the introduction of any cell into the solution would increase the efficiency of the operation. When the values for any cell $(u_i + p_{ij}v_j)$, computed as described,

* It is not necessarily true that in all cases a row or column can be found in which only one remaining unknown appears. Situations may be encountered in which there are two unknowns with two equations that have to be solved.

TABLE 4a
Initial Assignment (Total Cost $1,197,000)

Aircraft Type and Number		(1) N.Y.–L.A., 1 Stop	(2) N.Y.–L.A., 2 Stops	(3) N.Y.–Dallas, 0 Stop	(4) N.Y.–Dallas, 1 Stop	(5) N.Y.–Boston, 0 Stop	(6) Surplus Aircraft	(7) Implicit Values
	Passengers (1 = 100) →	250	120	180	90	600		
(1) A 10		10 / 18 / 16	/ 21 / 15	/ 18 / 28	/ 16 / 23	/ 10 / 81		$u_1 = -174$
(2) B 19			6.5 / 15 / 10	12.5 / 16 / 14	/ 14 / 15	/ 9 / 57		$u_2 = -82$
(3) C 25			/ 10 / 5		12.8 / 9 / 7	12.2 / 6 / 29		$u_3 = -23$
(4) D 15		10 / 17 / 9	5 / 16 / 11	/ 17 / 22	/ 15 / 17	/ 10 / 55		$u_4 = -91$
(5)	Deficit	/ 13 / 1	/ 13 / 1	5 / 7 / 1	/ 7 / 1	246 / 1 / 1		$u_5 = 0$
(6) Implicit Values		$v_1 = 12$	$v_2 = 9.7$	$v_3 = 7$	$v_4 = 4.6$	$v_5 = 1$	$v_6 = 0$	

TABLE 4b
Adjustment of Initial Assignment

Aircraft Type and Number		(1) N.Y.–L.A., 1 Stop	(2) N.Y.–L.A., 2 Stops	(3) N.Y.–Dallas, 0 Stop	(4) N.Y.–Dallas, 1 Stop	(5) N.Y.–Boston, 0 Stop	(6) Surplus Aircraft
	Passengers (1 = 100) →	250	120	180	90	600	
(1) A 10		10 / 18 / 16					
(2) B 19			$6.5 + 1.1\theta$ / 15 / 10	$12.5 - 1.1\theta$ / 16 / 14			
(3) C 25					12.8 / 9 / 7	12.2 / 6 / 29	
(4) D 15		10 / 17 / 9	$5 - \theta$ / 16 / 11	θ / 17 / 22			
(5)				$5 - 6.6\theta$ / 7 / 1		246 / 7 / 1	

exceed the costs (c_{ij}), it is economical to introduce that cell. For the cell (1, 2) it can be seen by inspection that this is not the case ($-174 + 15 \times 9.7 < 21$), and so on for the rest of row (1). Not until we come to row (4) is it possible to introduce a new activity, in cell (4, 3). There, the implicit values are $-91 + 22{\cdot}7$, which considerably exceeds the cost of $c_{43} = 17$. In fact, the difference of 45 (thousand dollars) represents the decrease in cost which will be achieved if one Type D can be devoted to the New York–Dallas run and the corollary adjustments made in accordance with the requirements of the problem. It would also be profitable to introduce cell (4, 4) since its implicit values total 27 as compared with a cost of 15. There is no other opportunity to introduce any activities at a profit.

Since cell (4, 3) promises the greatest possible saving per unit we shall introduce it. It is not always desirable to introduce the cell that promises the greatest saving, but this is frequently a good guide. In any case where familiarity with the characteristics of the industry in question indicates that on common-sense grounds some cell with an indicated saving less than the greatest is a more reasonable change in the existing set, it may be well to try it. Such a procedure may result in a reduction in the number of iterations required to attain an optimum solution.

Refer to Table 4b. How many units (aircraft) should be assigned to cell (4, 3)? Let $X_{43} = \theta$ be the number of aircraft to be introduced. If θ Type D's are introduced into cell (4, 3), these aircraft must come from other activities used in the initial assignment—that is, by adjusting the values of X_{11}, X_{41}, X_{22}, X_{42}, X_{23}, X_{53}, X_{34}, X_{35}, and X_{55}. From column (1) with $X_{11} = 10$, it follows $X_{41} = 10$ to carry the 250 (hundred) passengers, and hence it follows that $X_{42} = 5 - \theta$. This in turn requires, in order to serve the 120 (hundred) passengers on Route 2, that additional aircraft be assigned to Route 2 from some other source—i.e., by increasing the aircraft assigned to cell (2, 2). To provide the same passenger capacity in B's as has been withdrawn from D's, it is necessary (under our assumptions) to add 1.1θ B's. These, in turn, must come from cell (2, 3). The final adjustment is in cell (5, 3) which follows from the known adjustments in (2, 3) and (4, 3) and the fact that the passengers carried by the B's and C's on Route 3—plus those turned away—must total 180. The final step in this iteration is to determine the value of $X_{43} = \theta$. Since there will be a saving of \$45,000 for each unit increase in X_{43}, we shall make the assignment of aircraft to cell (4, 3) as large as possible consistent with the obvious condition that the adjusted assignments in the other cells are not negative. For extremely large θ, the assignments in (2, 3), (4, 2), and (5, 3) would be negative, and it is clear that the first cell to go negative with increasing θ will be cell (5, 3). Therefore, the maximum value that θ can have is that which provides sufficient additional capacity to carry 5 (hundred) passengers on Route 3 when θ D's are added and 1.1θ B's are removed from the route. The value of θ is $5/(6.6) = 0.75$. For this assignment the value of X_{53} vanishes. However, the number of assigned values remaining is again nine. (Nine corresponds to four aircraft equations plus five passenger equations.)

Enter into Table 5 in the upper left-hand corner of each cell the value of X_{ij} obtained by setting $X_{43} = \theta = 0.75$ in Tables 4a and 4b. Leave entry X_{53} blank as well as other unassigned cells. The first iteration is now completed.

In a similar fashion it is possible to continue iterating as shown in Tables 5, 6, 7, and 8 until no cells offer an opportunity for further economy by introducing them into the solution. It can be shown rigorously that this is an optimum solution. In the present case, an optimum was obtained after five iterations. The solution is presented in Table 8.

It is interesting to compare the original approximation (Table 3) with the final solution (Table 8). Note that the route with the longest stages (New York–Los Angeles one-stop) is served only by the four-engined airplanes—Type A's and D's—in both the first approximation and the solution. A significant change has been made, however, in the New York–Los Angeles two-stop route. In the first approximation, this route is served by 6.5 B's and 5 D's. In the solution, no D's are used on this route; instead 7.8 C's and 8 B's are used. The D's have been transferred to the New York–Dallas nonstop route, allowing a reduction in the B's on that route and their transfer to the New York–Dallas one-stop route. The latter route, in turn, in the final solution is being served exclusively by Type B's rather than exclusively by C's as in the original set. All these transfers allow, in effect, an increase in the C's on Route 5 from 12.2 in the original to 17.2 in the optimal schedule. Consequently, the number of passengers not served on the New York–Boston route is reduced from 246 (hundred) to 100 (hundred). Similarly, the passenger deficit on Route 3 has been eliminated.

Although little would be added to this exposition by describing the intermediate iterations in detail, it may be interesting to review Tables 5 through 8 which describe them. Each iteration results in a reduction of costs as follows:

	Total Variable Costs
First set	\$1,197,000
Second set	1,160,000
Third set	1,088,000
Fourth set	1,022,000
Fifth set	1,000,000

The total savings, then, amount to \$197,000.

It is possible for a person with some practice to perform each of the iterations in this problem in a few minutes. Some skill in such operations can be gained through practice and the use of a map. Some judicious guessing as to the most nearly optimal selection of the first set can reduce the number of iterations required; the exercise of common sense in selecting the cells to introduce in the process of iterating usually has the same result.

TABLE 5
Second Assignment (Total Cost $1,160,000), ($\theta = 0.7$)

Aircraft Type and Number	Passengers (1 = 100) →	(1) N.Y.–L.A., 1 Stop 250	(2) N.Y.–L.A., 2 Stops 120	(3) N.Y.–Dallas, 0 Stop 180	(4) N.Y.–Dallas, 1 Stop 90	(5) N.Y.–Boston 0 Stop 600	(6) Surplus Aircraft	(7) Implicit Values
(1) A 10		$10 - \theta$			θ			$u_1 = 18$
(2) B 19			$7.3 + 6.6\theta$	$11.7 - 6.6\theta$				$u_2 = 16$
(3) C 25					$12.8 - 3.3\theta$	$12.2 + 3.3\theta$		$u_3 = -23$
(4) D 15		$10 + 1.8\theta$	$4.2 - 6\theta$	$0.8 - 4.2\theta$				$u_4 = 17$
(5)	Deficit					$246 - 95\theta$		$u_5 = 0$
(6) Implicit Values		$v_1 = 0$	$v_2 = -0.1$	$v_3 = 0$	$v_4 = 4.6$	$v_5 = 1$	$v_6 = 0$	

TABLE 6
Third Assignment (Total Cost $1,088,000), ($\theta = 1.95$)

Aircraft Type and Number	Passengers (1 = 100) →	(1) N.Y.–L.A., 1 Stop 250	(2) N.Y.–L.A., 2 Stops 120	(3) N.Y.–Dallas, 0 Stop 180	(4) N.Y.–Dallas, 1 Stop 90	(5) N.Y.–Boston, 0 Stop 600	(6) Surplus Aircraft	(7) Implicit Values
(1) A 10		$9.3 + 0.36\theta$			$0.7 - 0.36\theta$			$u_1 = -89.8$
(2) B 19			11.9	$7.1 - \theta$	θ			$u_2 = -22$
(3) C 25					$10.5 - 0.96\theta$	$14.5 + 0.96\theta$		$u_3 = -23$
(4) D 15		$11.3 - 0.64\theta$		$3.7 + 0.64\theta$				$u_4 = -43$
(5)	Deficit					$180 - 29\theta$		$u_5 = 0$
(6) Implicit Values		$v_1 = 6.7$	$v_2 = 3.7$	$v_3 = 2.7$	$v_4 = 4.6$	$v_5 = 1$	$v_6 = 0$	

TABLE 7
Fourth Assignment (Total Cost $1,022,000), ($\theta = 7.8$)

Aircraft Type and Number	Passengers (1 = 100) →	(1) N.Y.–L.A., 1 Stop 250	(2) N.Y.–L.A., 2 Stops 120	(3) N.Y.–Dallas, 0 Stop 180	(4) N.Y.–Dallas, 1 Stop 90	(5) N.Y.–Boston, 0 Stop 600	(6) Surplus Aircraft	(7) Implicit Values
(1) A 10		10						$u_1 = 177$
(2) B 19			$11.9 - 0.5\theta$	5.2	$1.9 + 0.5\theta$			$u_2 = 54.55$
(3) C 25					$8.6 - 1.1\theta$	$16.4 + 0.1\theta$		$u_3 = -23$
(4) D 15		10.1		4.9				$u_4 = -93$
(5)	Deficit					$123 - 2.9\theta$		$u_5 = 0$
(6) Implicit Values		$v_1 = 12.2$	$v_2 = 6.96$	$v_3 = 5.0$	$v_4 = 4.57$	$v_5 = 1$	$v_6 = 0$	

TABLE 8
Fifth Assignment (Optimal) (Total Cost $1,000,000)

Aircraft Type and Number	Passengers (1 = 100) →	(1) N.Y.–L.A., 1 Stop 250	(2) N.Y.–L.A., 2 Stops 120	(3) N.Y.–Dallas, 0 Stop 180	(4) N.Y.–Dallas, 1 Stop 90	(5) N.Y.–Boston, 0 Stop 600	(6) Surplus Aircraft	(7) Implicit Values
(1) A 10		10						$u_1 = 136$
(2) B 19			8	5	6			$u_2 = -51$
(3) C 25			7.8			17.2		$u_3 = -23$
(4) D 15		10		5				$u_4 = -94$
(5)	Deficit					100		$u_5 = 0$
(6) Implicit Values		$v_1 = 8.55$	$v_2 = 6.6$	$v_3 = 5.5$	$v_4 = 4.33$	$v_5 = 1$	$v_6 = 0$	

Considerably more complicated problems—including more restrictions that provide greater realism—can be handled with computing equipment, but this simple solution by inspection provides a useful method of handling small problems in transportation with a heterogeneous fleet of vehicles.

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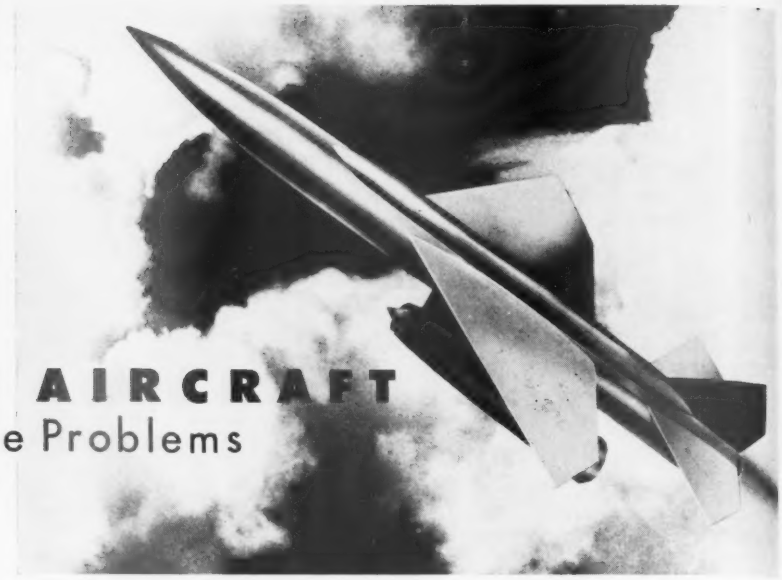
PILOTLESS AIRCRAFT
A Statement of the Problems



Cloaked in military secrecy, Boeing's F-99 Bomarc guided missile is shown in this sketch, which depicts it as a sleek delta-wing traveler.

CURTIS L. BATES*

Ryan Aeronautical Company

PILOTLESS AIRCRAFT are rapidly acquiring the versatility to span the spectrum of military missions. This trend is indicated by the increasing importance of missile and drone research and development in the aircraft industry. To illustrate the problems encountered in missile drone projects, such as the Ryan Firebee, it might be helpful to point out the differences between these air travelers and piloted planes.

For simplification, we shall confine our remarks to pilotless aircraft powered with turbojet engines, eliminating such categories as ballistic missiles and the short-range air-to-air missiles. The general problem areas can be broken down into air frame, propulsion, guidance systems, launching equipment, and the inevitable miscellaneous category that would cover such things as warheads and equipment required for special missions.

The pilotless aircraft field covers a range of sizes and missions, starting with target drones of perhaps 1,000 to 1,500 lbs. gross weight which require engine thrust of less than 1,000 lbs., and extending all the way up to the recently announced intercontinental bomber comparable in weight to a piloted bomber and requiring engines in our highest thrust categories. Let us examine problems in each of the areas listed above.

AIR FRAME

The air-frame problems are similar to those in piloted aircraft. There are, however, certain outstanding differences. Missiles, which are designed for a single flight and are to be expended at the end of the mission, do not have the requirements for repairability which we design into our piloted aircraft. The balance of production and operating costs against allowable weight and the required degree of aerodynamic cleanness must be viewed from the standpoint of the specific mission and operating conditions. This leads to a different set of compromises based on the different conditions, but the same factors enter into the analysis.

In general, the missile category should require less in the way of safety precautions than we require in a piloted airplane. However, there is a requirement for greater reliability in all the functional parts since there is no human pilot to compensate for a failing component. The general problem of reliability is one of the major problems facing all missile manufacturers. The proper fulfillment of a missile mission depends upon several hundred detail components performing with 100 per cent reliability under the conditions imposed.

The so-called thermal barrier is not a definite thing such as the sonic barrier. Rather it is a gradual increase in temperature with speed. A great deal of effort is being expended on the development of new materials for air-frame use in the high-temperature missile.

The problem extends much farther than the structure. Electronics equipment now malfunctions at temperatures as low as 200° F., and at these temperatures the life of many items of equipment is extremely short. Normal fuels are unsatisfactory for use in high temperatures, and it is difficult to provide adequate fuel cooling. Some warhead materials become unstable and dangerous at comparatively low temperatures. We are gradually invading this technical barrier as we settle more and more of the problems involved.

* Assistant Director of Engineering.

Propulsion

The turbojet engine is a relatively complex and costly piece of machinery, but for many applications it appears to be the logical power plant for missile use. A number of attempts have been made to develop an expendable turbojet engine. It has been found that an engine that is thoroughly reliable for a period of 1 to 20 hours—a normal life requirement for a missile engine—can be made reliable for a long period with little additional effort. Certain notable steps are being taken in the use of nonstrategic materials and high thrust ratings for short-period operations. The prospect of having a really cheap and expendable turbojet engine is not bright.

One area needing further and more rapid development in the propulsion field is the development of fuels with higher specific heats. Even higher density fuel with the same specific heat would be a considerable advantage, since total missile volume is highly dependent upon the fuel volume required.

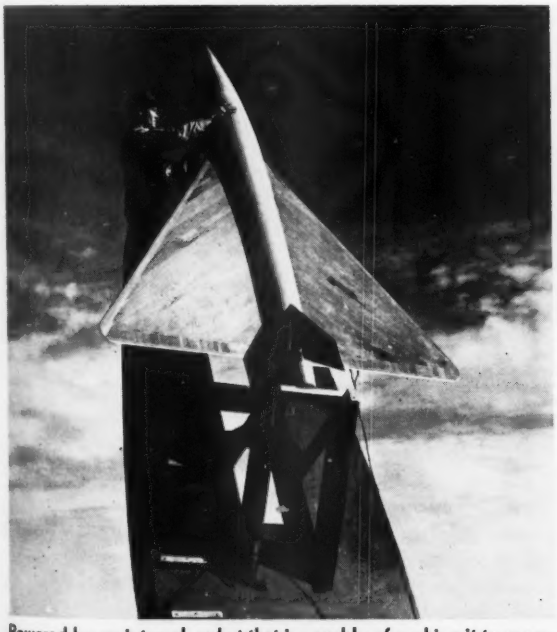
World's first pilotless plane was this Curtiss-Sperry "flying bomb" of 1917 which was developed for the U.S. Navy. Guided with an automatic pilot, it had a range of 50 miles and a top speed of 90 m.p.h.

Guidance Systems

Problems in the field of missile guidance are probably the most serious in the whole missile field. For short-range operation it is possible to resort to radio or radar control. The techniques for this type of control have been in use for some time and are now well worked out. This type of guidance is obviously limited by the range of the radio or radar system. It is, in addition, subject to interference and false commands from many sources. Some sources also feel that this method of control is particularly vulnerable to enemy action. The system is further limited since the accuracy decreases with the distance from the controlling station.

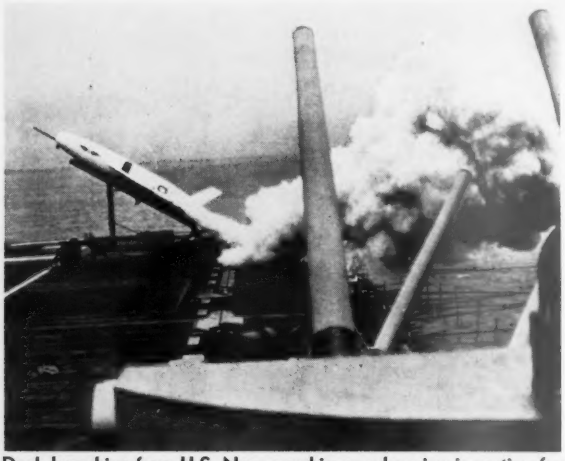
In long-range missile applications—more than a few hundred miles—it is necessary to resort to control that is not related to ground equipment. This might be done by straight dead reckoning but would require the accurate prediction of all disturbing influences, such as wind variations, and would require more accurate launching and control systems than appear practical.

The dead-reckoning system can be improved considerably by installing space references in the form of inertia units such as extremely accurate gyros. Even with these precise instruments the system is still faulty since



Powered by an internal rocket that is capable of pushing it to supersonic speeds, this research model of a delta-wing missile was developed by NACA to measure the amount of drag created by sharply swept, triangular wings.

Roaring into the sky from a small portable rocket launching device, the huge Martin Matador is a pilotless bomber that is powered by a full-scale turbojet engine.



Deck launching from U.S. Navy warship or submarine is routine for the Chance Vought Regulus—a radio-controlled missile with landing gear.

the inaccuracies increase with distance traveled. Divergence would be eliminated by use of celestial references, and the system can be made convergent by homing on the target itself. While many types of homing devices have been investigated, the problem of homing on an object several thousand miles away is obviously not a simple one.

The problem of reliability is more acute in the guidance equipment than anywhere else in the missile. Electronics equipment, in particular, has been difficult to produce with the required degree of reliability. Environmental conditions are such as to affect the operating characteristics of many pieces of guidance equipment, particularly the electronic ones. We require the same piece of equipment, operating at temperatures from perhaps 160°F. on the ground on a sunny day to −80°F. at high altitude and from sea-level pressures to the very low pressures at an altitude of 60,000 ft., to withstand exposure to the elements—perhaps many months before an emergency requires launching of the missile—and to be ready at any moment for such launching.

Launching

In the field of launching equipment, the problem is perhaps as much economic as technical. Many missiles are launched by means of rocket power, but it is not always realized that the cost of the rocket device, with a useful life of only a few seconds, may amount to as much as 10 per cent of the total missile cost. This, of course, is a cost for each launching and is in addition to the rather elaborate installations involved. A glance at recent press releases showing launching procedures gives a hint of what this cost must be. Rocket-type launchings appear to be the most practical method of getting a missile into the air, partly because it can be done in comparatively small fields. In some high-performance missiles we are approaching a thrust-to-weight ratio of one. When this figure is exceeded, it may be possible to eliminate the rocket cost by using vertical take-off on the missile engine thrust alone.

These are only a few of the many new problems facing the missile designer and the many old ones that are rendered more acute by new requirements and new operating conditions.

Last Call for Roster Listing

All members are reminded to send in their completed Roster Data Cards if they wish to change their listing in the next edition of the Roster. Members whose names do not appear in the 1954–1955 Roster are especially urged to return their cards immediately.

Those members not returning the data cards will be listed by repeating the entry that appeared for them in last year's Roster. This is your last opportunity to be correctly listed in the 1955–1956 IAS Roster.

23rd Annual Meeting

New York
Jan. 24–27, 1955

Summary of Technical Sessions

The Twenty-Third Annual Meeting of the IAS set new records for attendance, with 1,503 registrants for the technical sessions and more than 2,000 people attending the Honors Night Dinner in the Grand Ballroom of the Hotel Sheraton Astor, New York.

The 4-day Annual Meeting opened at 9:00 a.m. Monday, January 24, with simultaneous sessions on Aerodynamics and Structures. Summaries of the 74 technical papers presented follow, and many of the papers will be published in full in subsequent issues of the REVIEW and JOURNAL. Available preprints are listed on page 105.

The sessions follow in alphabetical order.

Aerial Surveying, Photographic and Electronic

Four papers were presented at the session on Aerial Surveying, held January 26 in cooperation with the Institute of Radio Engineers and the Radio Technical Commission for Aeronautics. Chairman of the meeting was Paul Rosenberg of Paul Rosenberg Associates.

Virgil Kauffman of Aero Service Corporation offered the first paper, "The Importance of Aircraft in Map Making and Exploration." He discussed the growth and far-flung operations of companies engaged in aerial map making and prospecting and called attention to the many inadequacies of the aircraft used for these purposes. During the past decade virtually all cartographic work has been completed with airplane photography as a foundation, he said.

Aircraft participate as a primary instrument in the world-wide search for minerals and oil by geophysical means. Special air-borne instruments of various types and functions have been developed which are usually flown at very low altitudes. They indicate the probability of oil but often point to deep underground deposits of minerals. The largest mineral deposits of great commercial value found in the United States and Canada in the present century were located from records obtained in aircraft flying at altitudes averaging 500 ft. above the terrain. Many radioactive deposits also have been located by low-flying aircraft carrying sensitive instruments.

H. C. Wroton of The Glenn L. Martin Company spoke on "Problems of Aircraft Construction for Electronic Magnetometer Survey or Detection." The air-borne electronic magnetometer, he said, dramatically illustrates the need for a "systems engineering" approach in achieving a successful and satisfactorily operating installation through careful integration of conflicting design requirements.

This extremely sensitive device is designed to detect minute changes in the magnetic field in which it operates—usually the field of the earth in a local area. Because of its great sensitivity, the magnetometer also detects the fields generated by magnetic parts and electrical conductors, including air-frame structural parts. Methods for neutralizing the interference caused by the aircraft are difficult to apply and involve lengthy and costly tests. Frequently, considerable air-frame structural modification is required. Millions of dollars have been spent in adapting existing air frames to carry magnetometer equipment successfully.

Design information has recently been accumulated which, if applied in the early stages of aircraft design, can greatly reduce the time and cost required to obtain a good magnetometer installation. The scope and nature of the information presently available were presented in this paper.

"Effects of the Systems Approach on Reconnaissance Equipment Design" was the subject of a paper by Irving Doyle of Fairchild Camera and Instrument Corporation. He pointed out that equipment design under a systems concept requires extensive consideration of overall system and component performance and must be based on a compromise of the best features of each subsystem. Instead of adding complexity, it is usually a requirement to reduce complexity—thus reducing weight and increasing reliability. New approaches to component design are needed to offer increased system flexibility without increasing complexity. Through the careful application of these principles and emphasis on optimizing the system, significant advantages have been gained in photo-reconnaissance systems in terms of increased capability and performance, reduced weight, space and power requirements, and improved reliability.

A paper on "Requirements of Military Aircraft Design for Aerial Photography" was presented by Brig. Gen. George W. Goddard, USAF (Ret.), of Bulova Research and Development Laboratories, Inc. He discussed problems involved in designing high-speed jet aircraft suitable for tactical and strategic aerial photographic reconnaissance at low, medium, and high altitudes and said the Air Force should have planes especially designed for reconnaissance instead of using modified bombers and fighters.

General Goddard pointed out that considerable research still must be done to provide proper environment in temperature and pressure for the camera station in aircraft. Vibration, a limiting factor in picture quality, becomes more serious with greater power and speed. Great strides have been made toward making possible more detailed photographs by developing gyroscopically stabilized camera mounts. Through the use of torquer mounts controlled by precise gyroscopes, the rotational movement of the aerial camera due to vibration or roll is restricted to a negligible value. Slower shutter speeds can be used, extending the operational day of the reconnaissance aircraft by several hours. Turbulent air flow in front of the camera window must be avoided, as it adversely affects image quality.

Aerodynamics—I

With Prof. John R. Weske of the University of Maryland as Chairman, the Aerodynamics meeting opened with a paper

by Theodore R. Goodman of Cornell Aeronautical Laboratory, Inc., entitled "Dynamic Derivatives in Yaw and Sideslip of Thin Wings at Supersonic Speeds." Information for the paper was derived from an Air Force project undertaken by Cornell Aeronautical Laboratory to compute the stability derivatives of certain specific aircraft and missiles, including stability derivatives for a large variety of wings.

There are three lateral dynamic attitudes, delineated by rolling, yawing, and sideslipping. It is possible to solve for the pressures on the rolling wing by quasi-steady analysis. But this approach is not applicable for the yawing or sideslipping wing, the two cases with which this paper dealt.

Two linear combinations of rolling and sideslipping were considered. In the first, sideslipping was zero (circular flight path), and for this case the pressures were found on an infinite swept wing. In the second, sideslipping and yawing were equal (straight flight path; turning wing), and for this case general formulas were derived for wings with an arbitrary supersonic leading edge and also for wings with a subsonic leading edge adjacent to a supersonic edge. The rolling moment associated with the latter motion was found for a number of useful plan forms.

Studies made with a hypersonic tunnel at Princeton University were described in a paper on "Fluid Dynamic Effects at Speeds from $M = 11$ to 15," prepared by Prof. Seymour M. Bogdonoff and Andrew G. Hammitt. They investigated the phenomena of viscous-inviscid interaction effects at very high speeds over the fore part of bodies, using helium as a working fluid and attaining speeds considerably higher than had been investigated previously. This blowdown tunnel has been operated at speeds up to $M = 15$, and increases in speed up to $M = 20$ seem quite possible with further development, the authors report.

Pressure distributions have been obtained over the fore part of some simple bodies: a flat plate, two wedges, and a cone. Schlieren and interferometric photographs have been taken. The results show that extremely high pressures, as high as ten times the values predicted by inviscid theories, are obtained over the region close to the nose of the body. Although some aspects of theoretical work on this problem appear to be correct, the numerical values of the pressures obtained are considerably different than predicted, on the order of two to three times as large. This difference may be explained by the influence of the leading edge, and some preliminary results on this effect are presented.

Describing work in NACA's Supersonic Free-Flight Wind Tunnel, in which a model can be fired from a gun into an onrushing stream of air moving at supersonic speed, Simon C. Sommer and Barbara J. Short of Ames Aeronautical Laboratory presented a paper on "Free-Flight Measurements of Skin Friction of Turbulent Boundary Layers with High Rates of Heat Transfer at High Supersonic Speeds." They said the average skin friction of a turbulent boundary layer in the presence of severe aerodynamic heating has been measured in the supersonic tunnel on free-flying, hollow-cylinder models at Mach Numbers of 2.8, 3.8, 5.6, and 7.0.

The skin friction measured under these conditions was appreciably higher than the skin friction measured on surfaces having zero heat transfer, experimentally confirming the trend of theoretical estimates. It was found that the high-heat-transfer skin-fraction data of the present investigation at Mach Numbers up to 7, the zero-heat-transfer skin-friction data obtained in previous wind-tunnel investigations at Mach Numbers up to 4.5, and the skin-friction data for heated pipe flow at subsonic speeds were in excellent agreement with the predictions of the T′ method of Rubesin and Johnson, slightly modified for turbulent boundary layers. On the basis of this broad scope of agreement, the modified T′ method appears to be the best available method of predicting skin friction of turbulent boundary layers at test conditions where no data exist.

In his paper on "Base Pressure Studies in Rarefied Supersonic Flows," L. L. Kavanau of Lockheed Aircraft Corporation described experimental procedures and results of a wind-tunnel study that was undertaken to learn something about the influence that high altitude will have on base pressures. Base pressures were measured on a simple cone-cylinder configuration over a range of Mach Numbers and Reynolds Numbers based on model length. The final results indicated that the base pressure decreased with decreasing Reynolds Number and increasing Mach Number, which was attributed to the completely laminar character of the boundary layer and critical wake region.

Preliminary tests showed a considerable variation of pressure existing over the base area, thus requiring an area-mean determination of the base pressure for every flow condition. Investigations were made of support interference effects arising from the relative size of both the sting diameter and sting length as compared to the model diameter. Some effects due to heat transfer were also studied. Supplementary pressure distributions were taken on the model surface upstream of the base and in the wake at one Mach and Reynolds Number that was characteristic of this flow regime. The base pressure coefficient in free-molecule flow was calculated for comparison purposes.

Aerodynamics—II

The second session on Aerodynamics was held January 25, with Prof. Antonio Ferri of Polytechnic Institute of Brooklyn in the chair. Four papers were presented.

Part of a study made under WADC contract to evaluate various aerodynamic control devices for gust alleviation was presented in a paper entitled, "A Method for Predicting Lift Effectiveness of Spoilers at Subsonic Speeds," by Arthur L. Jones, Owen P. Lamb, and Alfred E. Cronk of FluiDyne Engineering Corporation. While methods for estimating the lift effectiveness of ordinary flap-type control devices can usually be developed by application of thin airfoil theory, the authors said, control devices depending upon flow separation for their effectiveness, such as spoilers, have not proved amenable to analyses based solely on potential flow considerations. In the case of plain spoilers, a semiempirical approach utilizing both lifting-surface theory and experimental data provided a satisfactory basis for analyzing variations in spoiler lift effectiveness.

The method for prediction which evolved proved to be applicable at subsonic Mach Numbers up to approximately 0.95 for an angle-of-attack range restricted to an upper limit of about 6°. The method took into account the effects of the following parameters: aspect ratio, taper ratio, sweepback, airfoil thickness ratio, chordwise location and spanwise location of the control, and spanwise extent of the control. A design chart presentation showed the relative effects of variations in each parameter and provided for a rapid, straightforward prediction procedure.

M. W. Hunter, A. Shef, and D. V. Black, of Santa Monica Division, Douglas Aircraft Company, Inc., offered a paper on "Some Recent Aerodynamic Techniques in Design of Fin-Stabilized Free-Flight Missiles for Minimum Dispersion." The dispersion-reduction techniques discussed have primary application to ground-launched rockets and missiles, although the basic theories also have some utility in air-launched rocket design.

In the past, finned rocket design techniques were usually based on an attempt to restrict the flight-path angular deviation during burning by obtaining maximum possible longitudinal stability to decrease the effect of internal rocket disturbances. In recent years, with the increased interest in rocketry and guided-missile design, more sophisticated design techniques have been developed. These permit appreciable reduction in dispersion by considering the conflicting stability requirements from internal and external disturbances. Not

only was optimum compromise attempted but the component errors were attacked individually by fundamental spin programing (other than simple monotonic programs) and by utilization of techniques similar to those used in such fields as feedback theory and noise analysis. It was shown that the use of such combined techniques effectively reduces rocket flight-path angular dispersion.

"On Strong Transverse Waves Without Shocks in a Circular Cylinder" was the title of a paper written by Stephen H. Maslen and Franklin K. Moore of Lewis Flight Propulsion Laboratory, NACA. Pointing out that pressure oscillations of large, even destructive, amplitude are common in combustion chambers of present-day rocket and jet engines, the authors presented results of a study of large-amplitude pressure waves transverse to the axis of a cylindrical chamber representing a rocket or jet engine.

Whereas plane acoustic waves are known to steepen progressively into shocks, strong, permanently isentropic—that is, shock-free—waves can occur in the transverse modes, viscosity neglected. The form and frequency of these strong waves depend upon amplitude. The wall boundary layer causes, throughout the chamber, a steady second-order rotational flow ("acoustical streaming") with which there is associated a progressive damping of standing, but not traveling, transverse waves. The viscous dissipation of wave energy in the boundary layer itself was analyzed. The possible isentropy of strong transverse waves suggests that, if energy is suitably supplied—for example, by coupling with combustion—extremely violent waves may be more likely in transverse than in longitudinal resonance. This conclusion was further supported by consideration of boundary-layer dissipation, especially in short chambers.

The last Aerodynamics paper presented was "An Approximate Method of Calculating Three-Dimensional Compressible Flow in Axial Turbomachines," by Lt. Comdr. Carl O. Holmquist, USN, and Prof. W. Duncan Rannie of California Institute of Technology. The authors pointed out the two principal existing methods of calculating axially-symmetric compressible flow in turbomachines: (1) a simplified one-dimensional analysis and (2) numerical methods using the complete or linearized flow equations. The first is not satisfactory for multistage turbines with appreciable wall divergence; the second is tedious and time consuming.

The purpose of this investigation was to extend the approximate methods, successfully used in calculating incompressible flow in compressors with constant blade height, to the analysis of compressible flow in turbomachines with variable blade height. Assuming that the blades could be completely defined by the exit flow angle and neglecting the influence of downstream blades, the analysis was made considering the flow between successive blade rows only. With these restrictions, subsonic and isentropic supersonic flow patterns can be determined for compressor or turbine arbitrary boundary shapes as long as separation does not occur. Average losses can be accounted for by the use of a polytropic law, and the effect of radial variations in stagnation temperature can be included without difficulty. An example was given illustrating the flexibility and practical value of the iteration method that has been developed and the rapid convergence of successive solutions.

Aeroelasticity—I

The lectures on Aeroelasticity began January 24 and were continued the following morning. Under guidance of Prof. Lee Arnold of Columbia University, the first session started at 2:00 p.m. with a paper entitled, "An Investigation of the Flutter Characteristics of Compressor and Turbine Blade Systems," by Prof. Chi-Teh Wang, Prof. Frank Lane, and Robert J. Vaccaro of New York University. Fatigue failure of the blades of jet-engine compressors is probably caused by loads of aerodynamic origin, the paper said. The trend in blade design seems to aggravate the situation even further, as the blade shapes used are those with a high susceptibility to either forced or self-excited oscillation at large amplitude.

The paper presented results obtained in a combined theoretical-experimental research program aimed at exploring some of the peculiarities inherent in the flutter of compressor and possibly turbine blade systems. Numerical calculations were made on two-dimensional unstaggered as well as staggered cascades. For unstaggered cascades, the calculation showed this flutter occurs with adjacent blades oscillating 180° out of phase. It was found that, for staggered cascades, an extremely small change in blade inertial properties may cause a complete change of the blade flutter mode from one in which bending predominates to one in which torsion predominates.

Maurice A. Biot of Cornell Aeronautical Laboratory, Inc., gave a paper on "The Divergence of Supersonic Wings Including Chordwise Bending." In this paper, the static aeroelastic stability or divergence problem was investigated for thin supersonic wings when not only the spanwise bending and twist were taken into account but also the chordwise bending. The problem was treated in successive phases of increasing complexity from the two-dimensional curling-up of the leading edge to the three-dimensional stability of the cantilever wing. Several methods of approach were developed, including the nonlinear aspects of the structure and the aerodynamics. Results indicated a strong dependence of stability on Poisson's ratio and the magnitude of the deformation.

Speaking on "The Dynamic Response of a Large Airplane to Continuous Random Atmospheric Disturbances," Franklin W. Diederich of Langley Aeronautical Laboratory, NACA, pointed out that, in quantitative studies of some responses to continuous random turbulence, the effects of spanwise variation of gust intensity will have to be taken into account for large airplanes. In this paper the statistical approach to the gust loads problem, which consists in considering flight through turbulent air to be a stationary random process, was extended by including the effect of lateral variations of the instantaneous gust intensity on the aerodynamic forces and on the resultant motions and stresses of rigid and flexible airplanes. By means of some calculations of normal and rolling accelerations, as well as of the root bending moment, it was shown that these effects may be significant for large airplanes.

John F. McCarthy, Jr., and Prof. Robert L. Halfman, of Massachusetts Institute of Technology, outlined the basic problems of flutter testing in the low supersonic speed range (Mach 1.2 to 2.1) in their paper, "The Design and Testing of Supersonic Flutter Models." The paper reviewed the requirements for models that simulate full-scale airplanes when Mach Number is included as a parameter and compared these requirements with those where velocity is scaled so that flutter occurs in the range of a low-speed wind tunnel. A particular type of construction for supersonic flutter models was described in detail.

Methods of vibration testing, static testing, and flutter testing were discussed. In any flutter test, it was pointed out, it is more feasible to vary the flow parameters rather than the model parameters to obtain the neutrally stable flutter conditions. For supersonic flutter testing in the wind tunnel, significant changes in the flow parameters can be achieved only with a variable-geometry nozzle.

Aeroelasticity—II

Four more papers on Aeroelasticity were presented at the second session, with Alexander H. Flax of Cornell Aeronautical Laboratory, Inc., as Chairman. William R. Laidlaw, of North American Aviation, Inc., and Prof. Robert L. Halfman, of Massachusetts Institute of Technology, collaborated on a study of "Experimental Pressure Distributions

on Oscillating Low Aspect Ratio Wings." The distribution of lifting pressure over the surface of low aspect ratio wings oscillating in an incompressible flow was measured, and the results have led to a number of important conclusions regarding the relative status of existing lifting surface theories. Rectangular, sweptback, and delta plan forms were tested, as well as a wing-tip tank configuration. Measurements were made in both the low-speed flutter wind tunnel and still air, while the wings performed simple harmonic pitching and vertical translation motions. The pressures so obtained were then integrated numerically to yield lift and pitching moment distributions and total lift and pitching moment coefficients.

In a paper entitled "Aerodynamic Influence Coefficients for an Oscillating Finite Thin Wing in Supersonic Flow," Ta Li of Chance Vought Aircraft, Incorporated, presented a study—based on linearized theory—of the air forces of flexible thin wings oscillating harmonically in supersonic flow. A method for calculating the aerodynamic influence coefficients was proposed. This method approximates the pressure difference by dividing the region of integration into a mesh of congruent rectangles with diagonals parallel to the Mach lines. The spanwise integration is exact while the chordwise integration is approximated. A set of simple formulas for the influence coefficients was given. These can be handled conveniently by any type of high-speed computer. For subsonic leading edges, an imaginary diaphragm was considered to be in front of the leading edge, and linear equations expressing the condition of zero pressure difference off the wing were solved to find the corrections for the coefficients in the disturbed region. Tips were treated by a similar method.

John C. Houbolt of Langley Aeronautical Laboratory, NACA, read his paper on "Coupled Bending and Torsional Deformations of Twisted Rotating Blades Under Arbitrary Loading." In it, the differential equations of equilibrium for the lateral and torsional deformations of twisted rotating beams were developed for specific application to helicopter rotor and propeller blades. No assumption was made regarding the coincidence of the neutral, elastic, and mass axes, and the generality was such that previous theories fell out as subcases to the theory developed. Particular attention was given to the coupling that exists between the bending and twisting displacement as a result of centrifugal forces. The reduction of the general equations to the simpler well-known special cases was indicated. Also, a modal expansion procedure was indicated for solving the equations for various phenomena of concern to the designer, such as static loadings, natural vibration, divergence, and flutter.

Last of the Aeroelasticity papers was "An Approach to the Flutter Problem in Real Fluids," written by Prof. Nicholas Rott, of Cornell University, and M. B. T. George, formerly of Cornell. An approximate theory of airfoils in unsteady motion in a viscous fluid was proposed, in which viscous effects were accounted for by relaxing the Kutta condition and replacing it by a relation derived from experiments in steady flow. In this paper, applications were limited to moderate viscous effects below the stall. The possibility of one-degree-of-freedom flutter was discussed under this assumption. The discussion was partly extrapolated to the domain of stall flutter. Some possibilities of further development of this theory for the stalled case were indicated.

Aeronautical Engineering Education

On January 26 educational matters were covered by three speakers from industry in a joint session with the Aeronautical Division of the American Society for Engineering Education. Professor Leon Z. Seltzer of West Virginia University was Chairman.

Harold A. Bodley, of Convair Division of General Dynamics Corporation, delivered "Some Observations on Advanced Education for Aeronautical Engineers"; J. W. Carter, of The Glenn L. Martin Company, spoke on "Graduate Study in Aeronautical Engineering—an Air Frame Manufacturer's Comments"; and John C. Sanders, of Boeing Airplane Company, discussed the "Boeing Summer Faculty Program."

Air Transport

The evening session on Air Transport, presided over by Sanford B. Kauffman of Pan American World Airways, Inc., opened with the presentation of two related papers by R. C. Wanta of the U.S. Weather Bureau and R. P. Snodgrass of Sperry Gyroscope Company Division of The Sperry Corporation.

Speaking on "Direct Use of Rotating-Beam Ceilometer and Transmissometer in the Reporting of Ceiling and Visibility," Mr. Wanta described the development and characteristics of these two new instruments designed to help the pilot in bad-weather approaches. The ceilometer measures cloud height at frequent intervals, and the photo-electric transmissometer continuously determines visibility ranges. Preliminary experiments were summarized in the paper. Performance of the new equipment was described and discussed in terms of pilot observations at MacArthur Field, Ronkonkoma, N.Y. Performance data were given for day and night conditions and for three types of weather: "low clouds," "radiation fog," and "snow." The performance of a standard U.S. Weather Bureau airport station in the same weather was compared with that of the new instruments.

Mr. Snodgrass, presenting the results of "A Flight Investigation of the Performance of Low Ceiling Visibility Measuring Equipment," described a flight-test program undertaken to evaluate the rotating-beam ceilometer and the transmissometer and to study the problem of weather as seen from the cockpit. Actual weather test approaches were made both day and night, with the maximum emphasis on weather below 500 ft. ceiling and 1 mile visibility. A total of 468 actual weather instrument approaches were accomplished in a DC-3.

The problem was to determine if the new weather measuring system could be used to predict the three points on the approach at which the pilot would first be able to see the ground, the approach lights, and the runway. These three initial visual contacts from the cockpit were correlated with weather observations made on the airport and in the approach zone.

The author concluded that the transmissometer and rotating-beam ceilometer combination provide a sound method for remotely measuring weather in the runway approach zone. Supplementary photometric data are required. The manner in which weather is reported to the approaching pilot should be modified to include Vertical Contact Height, Approach Light Contact Height, Threshold Contact Height, and Runway Visual Range.

In "A Review of High-Altitude-Cabin-Pressurization Design Criteria Related to Future Transport Operations," L. M. Hitchcock of Boeing Airplane Company presented the problems associated with high-altitude flight for transports currently being designed and planned for commercial operation. He pointed out the types of damage that can occur to pressure cabins.

The design criteria necessary to provide safety and endurance of the overall structure—with the full recognition that some level of damage in the nature of punctures and/or tears should be contained—were outlined in this paper. Methods of obtaining reliability and safety of pressurized cabins for cases involving fatigue were also outlined. Development tests to demonstrate that the design goals have been reached and the coordination of these test results with the maintenance and inspection procedures for the airplane were discussed.

The mutual responsibility of the manufacturer and operator to preclude failures of a critical nature was discussed in terms of design, manufacturing, maintenance, and inspection. It

was concluded that higher altitude flight requires a reassessment of design criteria and substantiating tests and that safety can be achieved in a rational manner.

In his paper on "Design Considerations for Turboprop-Powered Cargo Aircraft," Winfield H. Arata, Jr., of Lockheed Aircraft Corporation discussed some of the design considerations and economic aspects of operating commercial turboprop cargo aircraft.

The paper was divided into two primary sections. First, cargo loading and cargo handling problems related to airframe design were analyzed. Particular attention was given to aircraft whose cargo loads would approach 50,000 lbs. The second part of this paper investigated the effect of turboprop engines on the operating cost of cargo airplanes. In particular, the direct operating costs of three different airplanes over the Los Angeles–Chicago route were presented. Detail factors in the Air Transport Association cost formulas were related to the total direct operating costs for each model.

Aircraft Design

Three papers on Aircraft Design were presented at the evening session, January 25, with Ivan H. Driggs of the U.S. Naval Air Development Center serving as Chairman.

J. P. Donald Garges of East Coast Aeronautics, Inc., the first speaker, discussed "Simplified Magnesium Air-Frame Design" and called attention to Air Force and Navy projects that employed thick-skin magnesium design techniques.

Experience in redesigning the outer wing panel of the F9F-2—substituting magnesium alloy for aluminum—and redesigning the entire structure of the F-80C to use magnesium alloy in place of aluminum showed that thick-skin magnesium air frames can be designed as efficiently from the strength–weight standpoint as most contemporary aluminum-alloy structures. From the standpoint of simplicity and cost reduction, the application of these magnesium design techniques to contemporary air frames has been responsible for the elimination of a large percentage of parts and fasteners, which would have a noticeable effect on the reduction of engineering time, as well as tooling and fabrication time. The resulting parts have not been complicated by this procedure.

New high-strength magnesium alloys exhibiting better elevated-temperature properties were discussed from the standpoint of future use in high-speed airplanes.

Speaking on "The Procurability Program of the Air Force," Otto H. Malz of Wright Air Development Center pointed out that the time and cost required for the completion of Air Force programs has continually increased with the growing complexity of Air Force material. It has become almost common belief that the growing complexity can be overcome only by the introduction of unique designs, new materials, specialized production equipment, and specialized techniques. This practice has taxed the aircraft industry and its supporting industries to an extent that compromises the flexibility of military planning. Mr. Malz explained the procurability program that is designed to remedy the situation; particularly, he showed the dominating part that the preliminary design personnel have in implementing the program.

Frederick M. Gloeckler of the U.S. Naval Air Development Center, in his paper on "Aircraft Design and Mission Compatibility," presented an analysis of a hypothetical and simplified military situation wherein the major factors and overall effectiveness of a military air transportation system were considered. The paper analyzed such considerations as the type of propulsion, the size and speed of the aircraft and their influence on the load and range capabilites, as well as the susceptibility to enemy action. Also included were the effects of the flight plan variation and the use of countermeasures on mission accomplishment.

The primary purpose of this paper was to illustrate how practical operations analysis techniques are being used to solve seemingly complicated problems in a rather simple fashion and to demonstrate the strong effect of large numbers of aircraft and the consequent reductions in aircraft size. Two points were stressed: (1) The performance of individual aircraft is not an adequate basis for measuring its worth. It is the group behavior in its operational environment which is of major importance. (2) The ever-persistent trend toward higher speeds and larger aircraft should not be tacitly accepted as a desirable one. During the preliminary design stages, a thorough operational analysis should be made to ensure that the selected design will be a reasonably effective one.

Aircraft Noise

T. L. K. Smull of the NACA served as Chairman of the session on Aircraft Noise, which was held January 25 in cooperation with the Acoustical Society of America.

Professor Peter J. Westervelt of Brown University presented the first paper, "A Comparison of British and American Work on Jet Aircraft Noise." Several theories for the generation of aerodynamic noise have been published, he said, since the appearance of Lighthill's classic work on this problem. Some of these more recent theoretical attempts are either in error or less general than Lighthill's original work.

The paper pointed out on theoretical grounds why noise measurements obtained on a jet engine operating in a test cell are so difficult to correlate with measurements obtained under free field conditions. Suggestions were offered for improving this correlation which, it is hoped, would remove some of the discrepancies existing between British and American published results on jet engine noise measurement.

"On the Acoustic Radiation from Boundary Layers and Jets" was the title of a dissertation by Prof. Hans W. Liepmann of California Institute of Technology. The sound field radiated from a flat plate boundary layer was interpreted as a pressure field due to displacement thickness fluctuations. These fluctuations determine a statistically distributed downwash field in the plane of the plate from which the potential, and hence the pressure, can be determined by Rayleigh's formula. The sound intensity is thus obtained in terms of a surface integral containing the space-time correlation function of the downwash velocity field. The same concept can be applied to the acoustic field of wakes and jets. In the case of axially symmetric flow displacement area fluctuations appear and the formalism is closely related to nonstationary slender body theory. The connection between this approach and Lighthill's theory of aerodynamically created sound was discussed, as well as the relation to experimental measurements and results.

"The Influence of Turbojet Engine Design Parameters on Noise Output" was the subject of a paper by D. M. A. Mercer and Ira Dyer of Bolt Beranek & Newman, Inc. The total acoustic power radiated by a turbojet engine appears to be a function of several variables, the authors said. The most satisfactory approach to correlation between engine operating parameters and noise output is dimensional analysis; the application of this technique was examined in some detail.

Some 40 acoustic measurements of different engines and conditions are available. A single variable such as thrust gives unsatisfactory correlation; several dimensionless quantities were examined, and one, using kinetic energy in jet stream, jet temperature, and diameter, gave good correlation not only for engines but also for model air jets. This conclusion was also substantiated by experiments in which engine operating conditions were carefully controlled over a small range. Precautions necessary to obtain meaningful values of engine operating parameters were discussed.

In a paper entitled "Recent NACA Investigations of Noise Reduction Devices for Full-Scale Engines," Edmund E. Callaghan, Newell D. Sanders, and Warren J. North of Lewis Flight Propulsion Laboratory, NACA, reviewed the latest available data on jet noise generation. Several investigators, they said, have substantiated experimentally Lighthills'

theory that the total acoustic power radiated by a simple jet discharging into quiescent air is directly proportional to the product of the eighth power of the jet velocity and the jet area.

Noise and engine performance data were presented for a number of devices that have been investigated in an effort to reduce the noise generation of jet engines. Toothed nozzles, ejectors, and screens were discussed in detail with respect to the changes in total acoustic power, directionality pattern, and spectrum distribution radiated by the engine. Several installations which resulted in resonant operation show the possibility of noise generation much greater than that predicted by Lighthill's theory.

Electronic Aids to the Aircraft Industry

Electronic Aids to the Aircraft Industry were covered in four papers read January 26 at a meeting held in cooperation with the Institute of Radio Engineers and the Radio Technical Commission for Aeronautics. Welcome W. Bender of the Glenn L. Martin Company was Chairman.

William R. Monroe of Northrop Aircraft, Inc., spoke on "Application of Electronic Simulation Techniques to the Development of Airplane Flight Control Systems." During the last ten years, he said, the electronic analog computer has become an almost irreplaceable tool in the design of airplane flight control systems. It allows much of airplane "flight" testing to be conducted on the ground and enables the engineer to observe airplane responses much more directly than has heretofore been possible.

The paper discussed the application of simulation in the initial design stages which cover ideal linear systems and expected nonlinearities. The development progresses to the use of the prototype system in breadboard form, together with simulation of the air frame, thus introducing real system nonlinearities, noise, crosstalk, limiting, hysteresis, backlash, and live pilot inputs. A further phase employs the prototype system in the flight-test airplane, including real conditions of installation and pilot inputs, but with the air-frame performance simulated. This results in "flying" the airplane on the ground. The final verification of the development is the "closed loop" flight test of the complete airplane.

"What Can Electronic Simulators Do for the Missile Designer?" was the title of a paper delivered by Floyd E. Nixon of The Glenn L. Martin Company. As the machines are very expensive, and their use is likely to cause an increase rather than a decrease in the size of the engineering staff, their economic justification must be firmly established. Electronic simulators perform routine computations quickly; but more important, they stimulate creative thinking.

A typical missile design problem was discussed in this paper. First, general types of control laws were investigated; then, more detailed problems were studied when the characteristics were better defined.

Problems which occur as a result of flight test performance also can be evaluated on the simulators so that an improved design will result, in many cases in the short time available between successive missile flight tests.

In discussing "The Flight Simulator Modification Problem," R. C. Dehmel of Curtiss-Wright Corporation pointed out that in the future, most simulators will be built and delivered well ahead of the first flight of the airplane represented. To the extent that simulators are built while aircraft are still on the drawing board or under X-model development, major modifications will occur during the construction and life of the simulator. The expedient handling of these changes is the most important current simulator problem. The decision whether or not to incorporate an aircraft change in the simulator must be based on training value.

In this paper, typical aircraft design changes were examined in relation to the problems of simulator modification and their solution. Engineering and manufacturing cost breakdowns and time schedules were given for a new simulator and for modification programs. The effect of computer-type equipment (e.g., digital or analog) on ease of conversion was discussed. Factors favoring field or factory conversion, kits or replacement units were outlined. Examples were cited to show that standardization cuts time and cost in conversions.

Francis B. Smith of Langley Aeronautical Laboratory, NACA, described "Analog Equipment for Processing Randomly Fluctuating Data" and illustrated its application to aeronautical problems.

Experimental studies of buffeting, flutter, and atmospheric turbulence produce data which are not amenable to analysis by the usual process of measuring or calculating discrete values of static force, pressure, or moment. Instead, where randomly fluctuating quantities are involved, it becomes necessary to use statistical methods to analyze and describe the phenomenon being investigated. The types of information usually required are probability distributions, power spectra, and cross spectra.

The NACA has developed electronic analog analyzers which make possible rapid and efficient processing of fluctuating data. Data from missiles, wind tunnels, or airplanes are recorded on magnetic tape and played back into equipment which automatically plots the analysis required. This method is not as exact as digital computation, but the accuracy is usually well within the statistical reliability of the data sample being analyzed. The time required per analysis is a few minutes, as compared to several hours required by other methods.

Flight Control Instrumentation

Charles H. Colvin of Colvin Laboratories, Inc., served as Chairman of the session on Flight Control Instrumentation January 27.

First of four papers presented was "Automatic Flight Control Requirements," by Frank R. Cook, formerly of Minneapolis-Honeywell Regulator Company. The paper presented an industry viewpoint of the broader aspects of the needs for automatic flight controls for manned military aircraft.

The continued development of aircraft of ever-increasing capabilities paces the need for the greater development of flight control and guidance equipment that will allow the operational accomplishment of all-weather missions beyond the capabilities of the unaided pilot, yet take full advantage of his capabilities. The development objective for control equipment should not be to replace the pilot; this should be left to guided missile designers. But these controls should be designed for minimum complexity to do things that the pilot cannot do by reason of the high-performance characteristics required or by reason of the multiplicity of tasks which must be performed simultaneously.

Mr. Cook concluded that although recent progress has been great, a very large job faces the aeronautical electronics and controls industries in fulfilling the military needs for automatic flight controls for current and future manned aircraft. It is to be expected that at least three generations of equipment and 10 to 15 years' time will be needed to complete the job.

George B. Johnson of Wright Air Development Center reviewed the operational concept and engineering design of past experiments in point-to-point automatic flight control in the introduction to his paper on "Past and Present Automatic Flight Control Development."

The paper described two Air Force research and development efforts, the Automatic Master Sequence Selector and a Landing Air-speed Control. The Automatic Master Sequence Selector is a control device which selects flight control parameters and equipment from preselected tape-coded information. A flight using the Automatic Master Sequence Selector is completely preplanned into sequences in which the flight parameters are discretely defined. Changes to the

established flight program can be effected through manual over-ride of individual control channels. The Landing Air-speed Control is an extension of previous air-speed control development employing angle-of-attack sensing as well as the more conventional air-speed reference and throttle controls. The results and problems of the program in a B-50 airplane were reviewed.

M. Gould Beard, of American Airlines, Inc., and Percy Halpert, of Sperry Gyroscope Company Division of the Sperry Corporation, collaborated in preparation of a paper on "Automatic Flight Control in Air Transportation." They presented the background of automatic flight control and discussed recent use of the automatic pilot in modern high-speed transport operations, particularly in American's coast-to-coast, nonstop DC-7 flights.

Touching upon the improvement in schedule reliability and decrease in pilot fatigue, the paper stressed economic savings based on the fact that the automatic pilot flies a straighter, more level course than the manual pilot, thus reducing flight time. High-speed turbine-powered aircraft will require an automatic flight control system with increased accuracy, new modes of control, and simplified pilot procedures.

B. C. Muzzey and V. J. Sims, of Boeing Airplane Company, discussed "A Wider Choice of Missile Control Instrument Functional Characteristics." The paper opened with the hypothesis that practical mechanical circuitry exists to build a guided missile control instrument capable of replacing several conventional control instruments plus associated electrical circuitry. Supporting this hypothesis, mechanical circuitry was demonstrated in a missile autopilot rate gyro having frequency characteristics specified independently of other characteristics. Gyro sensitivity to angular acceleration was eliminated as a first-order effect.

The mechanism employed was a shaped oil mass constrained to rotate in opposition to gimbal precession. Oil motion was harnessed to deflect the electrical transducer, giving further control of the instrument passband. A description of the gyro was presented, with design characteristics, plus confirming functional test results. The paper concluded by presenting a suggested design showing that the principles demonstrated in the rate gyro do in fact make practical a multiple-derivative instrument capable of supplying, in a single electrical output, the several types of dynamic information required for an automatic missile control channel. Use of such an instrument offers the possibility of greatly increased missile simplicity and reliability.

Flight Propulsion

E. M. Lester of Fairchild Engine Division, Fairchild Engine and Airplane Corporation, was Chairman of the Flight Propulsion session at which three papers were presented. P. N. Bright of the Allison Division, General Motors Corporation, opened the meeting with a discussion of "Structural Design Problems in Gas-Turbine Engines."

The paper covered specific structural design problems, describing stress analysis methods now in use at Allison Division and indicating where new methods are being developed or are needed. The following problems are discussed: disk wheel stresses, blade retention, external casing stresses, gyroscopic loads and I × P moments, bearing supports, split-line flange stresses, and interconnecting structure.

Static test results verifying some of the methods described were included. It was not the intent of this paper to be all-inclusive, but merely to list some of the problems encountered and how they have been handled. Problems were limited to those involving static and dynamic loads, omitting vibration, critical frequencies, etc.

"Before Afterburners" was the title of a presentation by Frank F. Rand, Jr., of the General Electric Company. The basic idea of this paper was to develop a good cruise engine and determine the advantages and disadvantages of adding heat to a basic engine either in an afterburner or high-temperature combustor upstream of the turbine. Merely for discussion, a comparison was made between the afterburner augmentation and the high-temperature turbine version of the basic engine over a range of flight Mach Numbers from 0.5 to 2.0 at altitudes of 20,000 to 80,000 ft.

It was concluded that good cruise performance may be developed for the selected basic engine with a turbine temperature of 1,500°F. to 1,800°F. over the pressure ratio range of 4 to 8 at sea level and upper altitudes. In comparing performance for the hot turbine engine and the afterburner engine over a range of altitudes, the hot turbine engine always looks better in specific fuel consumption. At altitude, the net specific thrust for the afterburner and hot turbine engine tend to approach each other at a flight Mach Number about 2.0. The hot turbojet engine will operate at higher altitudes than the afterburner version. Based on data at flight Mach Numbers below 2.0, it appears that more effort should be expended to increase the turbine temperature of new engine designs either with or without cooling in preference to augmentation development.

The evolution of modern turbojet engine control was illustrated in a paper by Donald F. Winters of Westinghouse Electric Corporation, "The Control of Turbojet Engines." The relatively simple jet engine, he said, has become overburdened with controls as a result of improved performance and expanded flight limits. Not only must the control system control a more complex engine, but it must do so with greater accuracy to fully exploit the potential performance gains now available.

Many of the control functions, such as the compressor flow control, have been necessitated by limitations of the engine. Others, such as the acceleration control, are necessary to relieve the combat pilot of responsibility. Still other control functions, such as the temperature trim control, have been required to maintain optimum engine performance. If the turbojet control system is to remain practical, a constant effort must be made to find simple means of doing the job. Two avenues of potential simplification were suggested.

Flight Safety

Charles Froesch of Eastern Air Lines, Inc., was Chairman of the Flight Safety session, held January 26 in cooperation with The Daniel and Florence Guggenheim Aviation Safety Center of Cornell University.

First of three papers presented was "Reliability and Safety as Design Parameters," by William Stieglitz of Republic Aviation Corporation. No evaluation of the overall capabilities of an airplane is realistic, the author pointed out, if it does not include reliability and safety. These factors, therefore, must be considered as basic design parameters, and given full weight in all design compromises. In many instances, adequate consideration of safety in the initial stages of design can result in the achievement of safety objectives without penalty in other respects. Frequently, the increased weight and complexity charged to safety features are the result of efforts to correct deficiencies after the design is already set. Even when some penalty is unavoidable, it can be held to a minimum if the problem is recognized in the initial stages.

The cost of accidents can far outweigh any potential savings gained by eliminating safety features. It has been estimated that a catastrophic accident to a present-day transport airplane results in a loss of approximately five million dollars. In military aircraft, lack of reliability results in excessive maintenance and aborted missions, if not loss of planes and men.

Methods were suggested for evaluating past experience, analyzing failures, and estimating the reliability of systems and components.

In his paper on "Escape from High-Speed Aircraft," Richard H. Frost of Stanley Aviation Corporation reviewed the evolution of emergency escape devices for high-speed aircraft. The paper described the original German and English developments which led to the basic U.S. Navy ejection seat and outlined fundamental research done by the U.S. Air Force.

The physiological, aerodynamic, structural, and environmental problems inherent in escape from present and future military aircraft were summarized, together with the resultant design criteria. Evolution of ballistic systems and other accessories of upward and downward ejection seats were described, together with four different types of escape capsule. After a survey of statistical results of escape from modern aircraft by the various methods currently in use, the paper closed with the author's views on the probable outcome of the current trend in emergency escape devices.

"Design Safety Aspects of the Boeing 707 Jet Transport" were discussed by E. W. Norris of Boeing Airplane Company, who said an attempt had been made to emphasize inherent simplicity and safety in the basic airplane design, rather than to add safety devices.

The paper enumerated methods of analyzing and utilizing operating experience from military and civil sources. Reliability analyses used to establish the probability of hazardous failures were discussed. Provisions were then made to minimize the consequences of remaining possible failures. The paper illustrated the application of these policies to the basic design as well as to component parts and systems.

One of the greatest single contributions to safety in the 707 is the operational simplicity of the power plant, the author said. The number of controls and displays in the cockpit is much smaller than in other large transports. Primary flight controls are all manually operated, with no power assist. Safety considerations were discussed in relation to lateral control, structural features, decompression, engine fire, and reliability of essential systems.

Helicopter Design

Five papers were read at the session on Helicopter Design, held on the last day of the Annual Meeting in cooperation with the American Helicopter Society. The Chairman was L. L. Douglas of Piasecki Helicopter Corporation.

E. F. Katzenberger and M. Rich of Sikorsky Aircraft Division, United Aircraft Corporation, presented a paper entitled, "An Investigation of Helicopter Descent and Landing Characteristics Following Power Failure." In this study, an analysis was made of the time history of descent velocity following power failure for a critical case of vertical take-off. The investigation was extended to include the determination of the time rate of change of descent velocity and velocity at ground contact following pilot control inputs, representative of pilot capabilities and on characteristics representative of current helicopters.

The special case of the steady state of rotative descents and landings was treated separately, and a factor was derived for comparing helicopter design as to autorotative landing capabilities.

Paul E. Hovgard of the Navy Department read a paper on "Comparative Performance of Convertiplanes, Helicopters, and Slow-Flying Airplanes." The study was limited to aircraft designed for carrying passengers or cargo over medium ranges. Component weights for a large number of production helicopters and airplanes were used as a basis for the estimation of weights of each of the three representative aircraft. All of them carried the same pay load and fixed load, but the speeds and ranges were selected arbitrarily as being most appropriate for the type. The power-required curves for each aircraft were then computed. The effect of the variations of the combustible load on the range and gross weight can easily be computed from the data given.

"The Kaman Hydra-Mechanical Clutch" was described by W. N. Stone and N. R. Richmond, of The Kaman Aircraft Corporation, in a paper setting forth the design criteria and principles of operation of an entirely new helicopter clutch and freewheeling unit concept. The power clutch described offers functional and pilot technique simplifications. Schematic diagrams and actual sectional views were included, development difficulties and their solutions briefly summarized, and advantages and growth potential, with specific weight data, given.

Speaking on "Helicopter Flight Vibration Problems," K. B. Gillmore of Piasecki Helicopter Corporation said the basic problem of helicopter vibrations in flight is to match the dynamic components with the structure so as to avoid excessive response to any of the cyclic forces in the system. Primarily, this matching requires that resonances be avoided, particularly with any of the lower harmonics of rotor speed. This is often difficult because these harmonics cover the range in which structure natural frequencies can be expected to lie. Much can be done by careful analysis in the design stage.

Various methods of changing frequencies were discussed. Where exciting forces are very large, avoidance of resonance is not enough and isolation must be provided. Other means of reducing excitation also considered included dynamic absorbers and control system changes.

In a paper on "Aerodynamic Design of Helicopters," Professor K. D. Wood of the University of Colorado developed an integrated series of helicopter performance charts covering hovering, level flight, climb, glide, and landing without power. The method used was a mathematical synthesis of theoretical equations with empirical coefficients to put the desired results in a form readily usable by engineers in making design compromises. This study will provide aeronautical engineers and students with a simple procedure for preliminary design of a helicopter for a specified pay load and performance.

Two basic series of charts were presented: (1) two new types of hovering-power charts and (2) a novel series of general charts for power required for level flight.

The hovering-power charts permit quick estimates to be made of the hovering power required as a function of various parameters, including solidity, disc loading, and tip speed with specified limits on retreating-blade stall and advancing-blade shock wave loss, and indicate the areas in which power-off landings may be hazardous. These hovering-power charts show quickly to the amateur or inexperienced designer what may have required long experience for professional designers to discover.

The level-flight charts consist of (1) a series of general charts of power required for level flight, expressed in terms of hovering power and (2) charts for level high speed and climb or glide as a function of the appropriate parameters.

Helicopter Dynamics

In a joint meeting with the American Helicopter Society on January 27, four papers were read and discussed under the guidance of Prof. R. L. Bisplinghoff of Massachusetts Institute of Technology, Chairman.

Alex Berman of The Kaman Aircraft Corporation described the "Response Matrix Method of Rotor Blade Analysis." His paper developed a new method of rotor blade analysis which permits the calculation of the blade response—i.e., bending moment, curvature, slope, deflection—for any loading and harmonic without repeating solutions of the differential equation. The response was calculated by post-multiplying the appropriate "response matrix" by a column matrix representing the rigid blade load distribution. The response matrices for the zeroth harmonic were calculated directly by tabular means, and an approximate method for obtaining these matrices for any higher harmonic was developed, using the natural frequencies and modes of the rotating beam. These frequencies and modes were themselves

obtained using the response matrices for the zeroth harmonic which yielded a secular equation in the natural frequencies.

Whenever a somewhat detailed study is to be made of a particular blade, a considerable time saving may be realized by use of this method. The response matrices, in addition to simplifying calculation of blade response under various loadings, will provide general information as to the dynamic properties of the blade. The possible effects of high harmonic loadings and more detailed calculation of loads may be obtained. The calculation of the rotating beam modes and frequencies was accomplished by a straightforward method not involving trial and error or iteration processes.

Lawrence Kaufman and Kenneth Peress, of Sperry Gyroscope Company Division of The Sperry Corporation, gave "A Review of Methods for Predicting Helicopter Longitudinal Response." The paper presented a dynamic analysis of the longitudinal motion of two types of helicopters in a form suitable for use by those with no special background in helicopter stability and control. The assumptions required to arrive at a practical formulation of the problem were listed and discussed.

Three methods of predicting helicopter longitudinal motions were presented, varying in complexity according to the number of degrees of freedom that were permitted. Sample calculations were made to show how the analysis may be applied to practical helicopters, and a comparison was made between calculated response (using varying degrees of simplification) and measured response.

"Notes on the Effect of Extreme Operating Conditions on Helicopter Blade Flapping" was the title of a paper by Robert J. Tapscott and F. B. Gustafson of Langley Aeronautical Laboratory, NACA. As compared with more conventional types, they pointed out, blade-fuselage clearance for higher-performance, higher-speed helicopters is more difficult both to provide and to estimate or study. As a step toward clarifying the problems involved, this paper endeavored to summarize the present state of knowledge.

Conditions involving severe blade stalling were given primary consideration, and the available evidence concerning the suddenness with which increased flapping may thereby develop was examined. Theoretical effects of transient control motions during a severe maneuver were illustrated for the case of mass-balanced blades. The most detailed examination given was for tip-speed ratios of about 0.3. For such tip-speed ratios the combined indications of theory and experiment were that severe maneuvers may, for some combinations of variables, result in downward-flapping values of the order of 15° below the plane of the rotor hub.

"Stability of a Flexible Helicopter Rotor Blade in Forward Flight" was discussed by Yechiel Shulman of Massachusetts Institute of Technology. The paper considered the problem of the stability of the transient motion in the flapping plane of a flexible helicopter rotor blade in forward flight at advanced ratios above $\mu = 1$.

The formulation of the problem considered two degrees of freedom: rigid flapping and elastic bending. A new method of determining the transient stability of the motion was developed, using the concept of Stability Number. It was shown that the results obtained by inclusion of the elastic degree of freedom agree with experimental results to a much larger extent than was achieved by analyses neglecting blade flexibility.

Historical Meeting

At an evening session on January 26, Capt. J. Laurence Pritchard, former Secretary of the Royal Aeronautical Society, spoke on "The History of Aeronautics in Great Britain and Its Relation to the Royal Aeronautical Society and the Institute of the Aeronautical Sciences."

Instrument Systems and Simplification

With C. F. Savage of General Electric Company as Chairman, the session on Instrument Systems and Simplification opened January 27 with a paper by Lt. Comdr. George W. Hoover, USN. It was entitled, "Instrument Simplification."

The paper discussed the importance of presentation in the development of instruments, outlined the weaknesses of all instrumentation, stated the types of presentation required for aircraft instruments, and emphasized that proper teamwork is required to design properly. A methodology was established for display design for orientation instruments that provide data normally obtained from visual contact, without permitting the design decisions to be influenced by personal opinion. If this methodology is followed, regardless of who the designer is, the instrument display always will be fundamentally correct because it will have met not only the operational requirements, but the psycho-physiological requirements as well. Proper presentation, based upon scientific principles, would reduce instrument flying training to an absolute minimum.

"A Compass-Controlled Directional Gyro System for Today's Fighter Aircraft" was described in a paper by Harold E. Trekell and Harold S. Whitehead of General Electric Company. Figures showed the Navy type MA-1 Compass System, designed as a successor to the G-2.

The authors discussed the evolution of the compass system design from the design engineer's viewpoint, as well as the operational requirements of the user. They discussed representative design decisions and compromises of complexity, weight, size, reliability, and accuracy which must be made to obtain an optimum system with satisfactory performance which can be produced in quantity at reasonable cost. The added complexity of today's system to meet stringent specifications and operation requirements was noted.

"The Floating Integrating Gyro and Its Application to Geometrical Stabilization Problems on Moving Bases" was the subject of a paper by Prof. Charles S. Draper, Prof. Walter Wrigley, and Lester R. Grohe of Massachusetts Institute of Technology. The basic problem of space integration from the fundamental laws of motion was discussed in this paper. This was followed by a generalized theory of gyro instrumentation with particular application to the single-degree-of-freedom integrating gyro. The integrating gyro was further discussed in its essential features and possible means of utilization with a servo drive as a method for instrumenting the space integrator. This was illustrated by data taken from laboratory tests of a gyro-monitored servo-driven turntable.

In his paper on "The Newest Instruments for Astronomical Navigation," Victor E. Carbonara of Kollsman Instrument Corporation, Subsidiary of Standard Coil Products Co., Inc., described a new, lightweight, automatic sextant, supplemented by computing devices so that the obtaining of position data by astronomical methods can be carried out very frequently and more expeditiously. This newest instrumentation represents a great simplification of the completely automatic systems envisaged in the recent past, with a correspondingly great reduction in cost compatible with the requirements of the transatlantic jet transports of tomorrow.

JATO for Aircraft

At a joint meeting with the American Rocket Society on January 27, four papers were presented on JATO for Aircraft. R. W. Porter of General Electric Company presided.

The session opened with a paper by H. W. Ritchey of Thiokol Chemical Corporation on "Thrust Program of Solid-Propellant Boosters by Choice of Propellant Configurations and Compositions." This paper presented the fundamental principles of solid-propellant thrust units—

JATO's, boosters, and rockets—in order to demonstrate that the performance of such units is based on sound fundamental principles which are predictable and which can be applied to any given design with complete confidence.

In order to attain the required performance from a unit having specified physical dimensions, the designer can choose from a wide range of propellant characteristics and a wide variety of charge configurations. A number of configurations were shown in order to demonstrate that almost any desired thrust-time characteristics can be attained by proper charge design.

C. J. Libby of The Glenn L. Martin Company spoke on "Zero-Length Launch for Matador." The paper described the evolution of zero-length launch technique for the Air Force TM-61 Matador, which resulted in the world's smallest airport for a tactical bombardment missile. It also described the design problems encountered and solved and, in addition, gave some historical data on the testing performed. A short motion picture supplementing the paper showed some of the early zero-length launch tests at Aberdeen Proving Ground, as well as recent shots of Matador launchings, including in-flight and terminal-dive pictures.

"The Application of JATO to Civilian Aircraft" was the topic of Robert L. Hirsch of Aerojet-General Corporation, Subsidiary of the General Tire & Rubber Company. Since 1942, the paper pointed out, more than a quarter-million JATO motors have been used by the Armed Services. This backlog of experience on military aircraft has stimulated interest in the application of such units to civilian aircraft. Three civilian applications of considerable importance are for commercial passenger and cargo air lines, for personal or executive aircraft, and for agricultural flying services.

The paper discussed the findings of several commercial air lines that have tested JATO entensively and employ it for scheduled flights. Increased pay loads and added safety are derived benefits. New JATO units being developed for the military services should be available soon for civilian applications. They will have better handling characteristics while retaining the ruggedness and reliability of the present motors. With the advent of high-performance, jet-powered commercial aircraft and their more severe take-off problems, the civilian use of JATO should become even more prevalent.

The session closed with a paper on "The Advantages of Liquid-Propellant Rocket Engines for JATO," by D. F. Ferries of Reaction Motors, Inc. It discussed the advantages of liquid-propellant power plants for either versatile, repeat-use JATO's, or simple, expendable JATO's.

Liquid JATO's are characterized by low propellant cost and high propellant availability, because common industrial chemicals are used directly, without further processing. Existing, widely dispersed facilities can meet large propellant demands without vast capital expenditures for specialized, vulnerable armament plants.

Repeat-use JATO's allow pilot-controlled operation and provide high performance. They are complex and costly on a dollars/lb. thrust basis, cheap on a dollars/take-off basis. Expendable JATO's are simple and cheap on a dollars/lb. thrust basis. Liquid JATO's have been simplified and are highly competitive with solid JATO's, particularly in larger sizes.

Meteorology

A. F. Merewether of American Airlines Inc., was Chairman of the session on Meteorology, held January 26 in cooperation with the American Meteorological Society.

"Some Recent Reports of Severe Air Turbulence and the Problem of Their Interpretation" were discussed by Patrick J. Harney of the Geophysics Research Directorate, USAF. The paper was based on pilot reports of five encounters with severe turbulence which furnished new meteorological information. For the first time, lateral forces demand attention from the designer as isotropic eddy structure is verified. Strength requirements are met by modern design but control problems become exaggerated. The reports were examined in relation to the behavior of airplane instruments and pilot's reaction.

"Some Air-Borne Measurements of Atomic Debris" were discussed by Lester Machta of the U.S. Weather Bureau.

Relative measurements of radioactivity along two flight lines in the central and eastern part of the U.S., he said, provide horizontal profiles of the concentration of atomic debris for meteorological analysis. The majority of the profiles obtained between 8,000 and 30,000 ft. showed the irregularities that are typical of the action of atmospheric turbulence superimposed on vertical wind shear.

From a few profiles that exhibited the characteristics predicted by theory, an estimate of the "effective" coefficient of lateral eddy diffusion was produced which was of the order of 10^8 cm^2 sec^{-1}. Further, a comparison between the predicted position of the cores of the atomic clouds based on meteorological trajectories and the observed position of maximum radioactivity, together with verifications of balloon flights, suggests that the accuracy of meteorological trajectories decreases with height as the quantity and quality of upper-air information deteriorates.

"The Relationship of Clouds and Atmospheric Electricity to Jet Stream Wind Maximums" was the subject of Vincent J. Schaefer of The Munitalp Foundation, Inc. This paper presented more evidence of the relationships of distinctive cloud forms and a high level of atmospheric electricity to jet stream maximum wind velocities. Time lapse motion pictures illustrated some of the spectacular cloud effects that occur. Such observations have now been made in Japan, Idaho, California, New York, the North Atlantic, and Germany. Cloud and condensation trail studies give promise of providing detailed information of the microstructure of jet stream winds. Unusually high levels of atmospheric electricity may serve to locate wind maximums when cloud forms are absent.

Professor Alfred K. Blackadar of The Pennsylvania State University spoke on "The Low-Level Jet Phenomenon," the sharp maximum of the wind profile which often develops at an elevation of less than 5,000 ft. above the ground. It is best developed at night, and the wind speed maximum usually occurs at the top of the nocturnal inversion.

When the frictional restraint imposed by the daytime mixing is released by the formation of a surface inversion, the air begins to execute an inertia oscillation. Within the growing inversion the motion is partially suppressed by a downward loss of momentum, but above the inversion the motion is nearly frictionless. The oscillation results in supergradient winds during the latter part of the night and usually a noticeable reduction of speed before dawn. In the best developed examples, there was a decrease of pressure gradient with height.

The extreme wind shear that tends to result beneath such inertia oscillations is an important factor in explaining the upward growth of the nocturnal inversion. The low-level jet also plays a prominent role in the formation of nocturnal thunderstorms by providing a nocturnal increase of low-level convergence and warm advection.

Soaring Flight

One of the final sessions of the Annual Meeting was devoted to Soaring Flight, on January 27, in cooperation with the Soaring Society of America. The Chairman was Ralph S. Barnaby of The Franklin Institute Laboratories for Research and Development.

Harry N. Perl of Nelson Specialty Corporation spoke on "The Powered Sailplane," describing many of the design problems encountered in developing the Nelson Humming-

bird, its structural aspects and the type of construction and materials employed, and its flight characteristics.

A panel discussion on "Contributions of Soaring to Aviation Progress—Past, Present, and Future" was led by W. B. Klemperer, Ernest Schweizer, E. G. Stout, Paul A. MacCready, Jr., 1st Lt. Fred Obarr, USAF, and A/C John Bardwich, USAF.

Stability and Control

William F. Milliken, Jr., of Cornell Aeronautical Laboratory, Inc., was Chairman of the session on Stability and Control, held on the afternoon of the opening day. First of the three papers presented was "Automatic Feedback Control and All-Weather Flying," by Dunstan Graham and Major Richard C. Lathrop of Wright Air Development Center. A large part of the difficulty in operating aircraft in adverse weather, the authors point out, revolves around precise control of the flight path in the absence of visual reference to objects outside the cockpit. The inherent powerful advantages of high-gain automatic feedback control can be applied to the solution of this problem.

These advantages are, however, attended by disadvantages, such as the tendency toward dynamic instability and susceptibility to spurious signals or "noise." A successful match of the elements in an automatic feedback control loop is dependent on detailed knowledge of the mechanics—particularly the dynamics—of each element in the loop. Existing theories are not always an adequate basis for this knowledge, and an extensive program of experimentation is required. Examples from the experience of the All Weather Branch of WADC were cited to illustrate how a knowledge of the mechanics of aircraft response to control, automatic pilots, radio aids, and radar references is developed through flight research. Although successful automatic feedback systems for all-weather flight control have been synthesized, the more general problem of synthesizing systems of optimum dynamic performance, cost, and reliability remains for the future.

"NACA Applications of Variable-Stability Airplanes in Lateral-Stability Research" were discussed in a paper by William M. Kauffman and Fred J. Drinkwater III of Ames Aeronautical Laboratory, NACA. The phrase "variable-stability airplanes" refers to piloted airplanes whose stability characteristics can be varied by servo-actuation of control surfaces.

The paper briefly described equipment developed for varying in flight the lateral and directional stability characteristics of two fighter-type airplanes. Emphasis was given to the research-tool possibilities offered by the large number and ranges of variable-stability derivatives and associated lateral-oscillation characteristics. Some of the research applications are: (1) flight surveys over wide ranges of lateral and directional behavior of present and future operational interest, in order to illuminate potential flying-qualities problems and provide data useful in establishing related specifications; (2) flight simulation of possibly undesirable characteristics predicted for proposed airplanes, in order to assist the designer; and (3) flight evaluation of promising types of stability-augmenting devices, such as yaw dampers.

Waldemar O. Breuhaus of Cornell Aeronautical Laboratory, Inc., read a paper on "Flight Research Utilizing Variable-Stability Aircraft." He described flight research programs using airplanes specially equipped with servo-operated controls permitting simple and rapid modification of the apparent static and dynamic stability and control forces of the airplanes. The control surface deflections required to modify the apparent stability characteristics of the aircraft were obtained without corresponding motion of the pilot's cockpit controls, while control surface deflections caused by the pilot were obtained by normal manipulation of the cockpit controls. The control forces felt by the pilot were independent of the aerodynamic hinge moments and could be varied through wide limits. Adjustment of the stability and control force characteristics of these aircraft could be made easily during flight. These variable-stability airplanes have proved to be useful and versatile tools for conducting flight investigations to determine the acceptability to pilots of various aircraft handling characteristics.

Structures

Four papers were presented in the Structures session, under the chairmanship of S. B. Batdorf of Westinghouse Electric Corporation. Paul H. Denke of Santa Monica Division, Douglas Aircraft Company, Inc., one of the first speakers on the opening day of the Annual Meeting, read his paper on "The Matric Solution of Certain Nonlinear Problems in Structural Analysis." In this, he applied the matric formulations of the equations of equilibrium and of the Maxwell-Mohr equations of continuity to the solution of certain nonlinear problems in the analysis of indeterminate structures. Only nonlinearities in the elements of the flexibility matrix were involved in the class of problems under consideration. Such problems were characterized by the dependence of the flexibility matrix upon the internal loads. Nonlinearities resulting from plasticity and from certain types of buckling have this characteristic. The analysis was applied to a simple indeterminate structure in which the members were considered to exhibit first, plasticity, and second, buckling. The high-speed digital computer was utilized in solving the nonlinear matric equations.

Paul Seide of Northrop Aircraft, Inc., offered the second Structures paper, entitled "Elasto-Plastic Bending of Beams on Elastic Foundations." The paper compared two methods for the determination of elasto-plastic deformations of elastically supported beams having a bilinear stress-strain curve. One method involves the numerical solution of the fourth-order nonlinear differential equation associated with the engineering theory of beam bending; the other linearizes the problem by replacing the nonlinear moment-curvature diagram with its linear asymptotes. Results obtained through the two methods were in excellent agreement. The linearized method was recommended for investigation of the initial phases of bending of elastically supported beams in which only a few plastic regions appear. Neither method has any particular advantages when the beam has many plastic regions—i.e., both methods involve a tremendous amount of computation. Computed deflections for finite elastically supported beams are in good agreement with experimental results; differences of five per cent are consistent in the elastic and in most of the plastic regions.

Professor P. E. Sandorff of Massachusetts Institute of Technology, formerly of Lockheed Aircraft Corporation, spoke on "Design of Structural Models, with Application to Stiffened Panels Under Combined Shear and Compression." This paper presented practical methods for the design of structural test specimens, based on the principle of exploring a specific mode of failure rather than the customary indefinite investigation of structural behavior in general. This approach makes possible considerable simplification in specimen construction, through application of similitude relations, without introducing unknown restrictions on the validity of the results.

Illustration was provided by application to the problem of interaction relations for stiffened-skin panels under combined compression and shear. Results of full-scale tests, under simultaneous bending and torsion, of a box beam structure incorporating machined integrally-stiffened test panels substantiate the interaction curve derived by similitude relations. Professor Sandorff's fundamental thesis was that geometric similarity between the test specimen and the original is not always a requirement for a valid structures test, much less for one of only engineering accuracy.

A paper by Prof. Luigi Broglio of the University of Rome described the "Balance-Method Applied to Swept-Wing Stress-Analysis." The Balance-Method, devised by Professor Broglio, can be applied without any essential modification to a great variety of problems in the field of applied mechanics. In this paper, the essential purpose was (1) to reduce the problem of the swept wing under whichsoever load distribution to that of the same structure under a special load distribution constituted by self-balanced systems of forces and (2) to supply a general procedure of successive approximations such that, at every step, all the "residuals" be again self-balanced systems of the same type. The advanced problem of the swept wing was solved in an exact way with only the use of quite simple numerical operations. For any type of wing or fuselage, the equations of the problem can be written in such a way that, for each section, only the distortion parameters (as unknowns) and only self-balanced systems (as known terms) appear, so that a uniform and objective technique of successive approximations can always be used for numerical computations.

Sherman M. Fairchild Publication Fund Papers

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101	Introduction to Shock Wave Theory—J. G. Coffin.	$2.65	$3.50
100	Blade Pitching Moments of a Two-Bladed Rotor—R. W. Allen.	$0.75	$1.00

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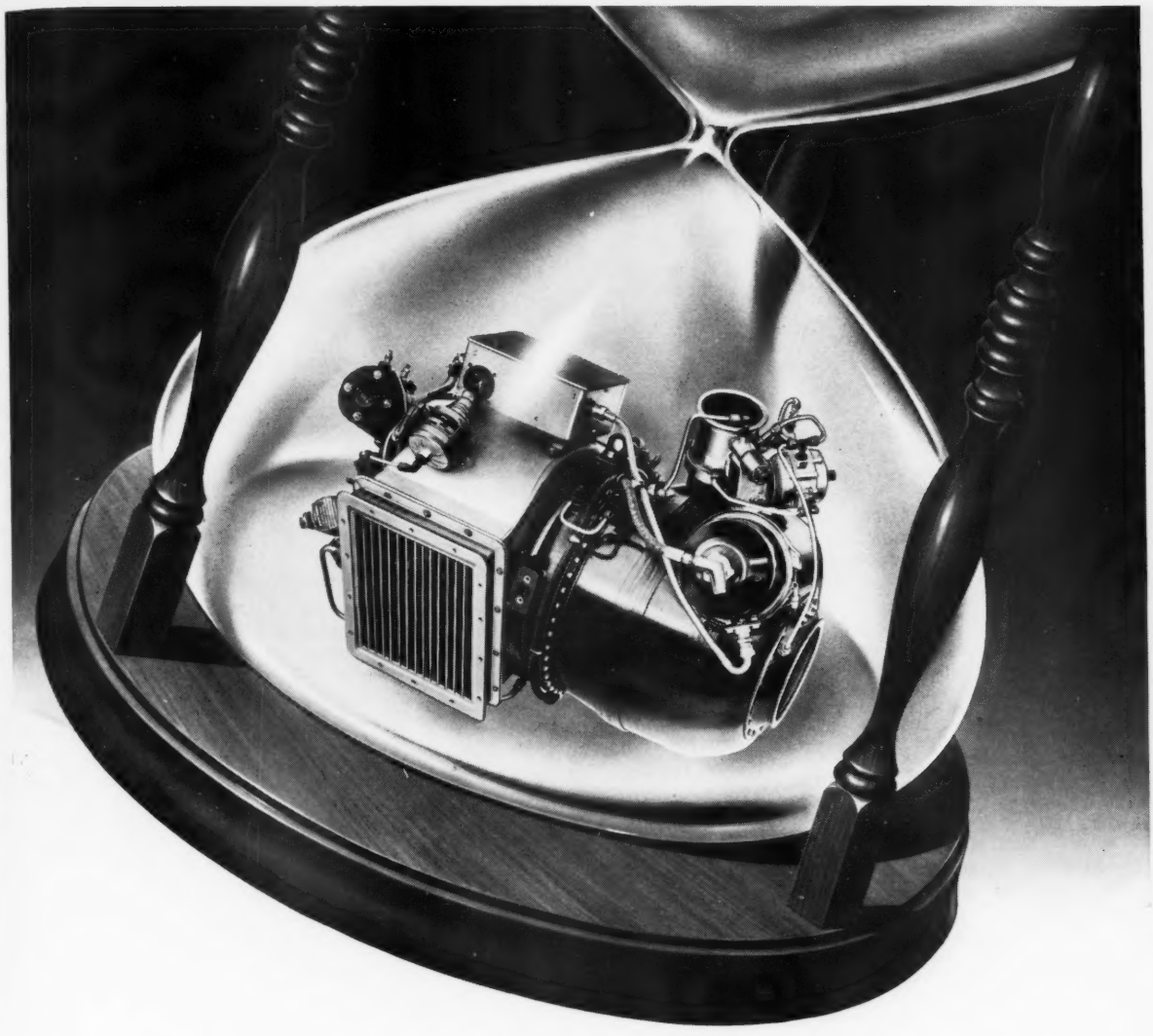

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IAS News

(*Continued from page 37*)

Robert G. Averill (AM), Consulting Economist and Traffic Engineer, Woodstock, Vt. Formerly, Captain, USAF, Navigator, 18th Air Force.

J. E. Barfoot (AF), Project Engineer—Structures, KC-135 Jet Tanker Project, Boeing Airplane Company. Formerly, Engineering Manager, Moses Lake Flight Center, Boeing.

Niels C. Beck (M), now Assistant Manager, Program Development, Armour Research Foundation, Illinois Institute of Technology.

Dr. William Bollay (F), President, Aerophysics Development Corporation, recently purchased by and now a Subsidiary of Studebaker-Packard Corporation. Formerly, President, Aerophysics Development Corporation.

Joseph C. Buechel (M), Manager, MX2273 Project, Small Aircraft Engine Department, General Electric Company. Formerly, Project Engineer, Aircraft Accessory Turbine, G-E.

Harry A. Carter (M), Manager, Market Research and Operations Analysis Section, Sales Department, Boeing. Formerly, Preliminary Design Group Engineer, Jet Tanker-Transport Military Configuration, Boeing.

Laurance H. Cooper (AM), now with Hall-Scott Motors Company, Berkeley, Calif. Formerly, General Manager, Aircraft Division, Rheem Manufacturing Company.

Dr. Robert A. Cornog (M), Physicist, Guided Missile Research Division, The Ramo-Wooldridge Corporation. Formerly, Director—Research, Pacific Mercury Research Center.

Hans U. Eckert (M), Senior Aerodynamics Engineer, Convair-San Diego Division of General Dynamics Corporation. Formerly with Aeronautical Research Laboratory, Wright Air Development Center, Wright-Patterson AFB, Ohio.

Clifton T. Foss, MIAS, has been appointed Assistant General Manager of American Bosch Arma Corporation's Arma Division. He continues as Vice-President—Engineering. Mr. Foss, a 1929 University of Wisconsin Electrical Engineering graduate, has been with Arma since 1933.

Melvin P. Espy (M), Assistant Director of Engineering, Anaheim (Calif.) Division, Northrop Aircraft, Inc. Formerly, Chief, Special Weapons Section, Canadair Limited.

David C. Fulton (M), Manager, Marine Sales, Steam Division, Westinghouse Electric Corporation. Formerly, Pacific Coast Regional Manager of Marine, Aviation, and Transportation Sales, Westinghouse.

Stuart H. Hahn (M), Engineering Specialist, Mechanical Development Section, Electronic Defense Laboratory, Sylvania Electric Products, Inc. Formerly, Engineering Consultant, Dalmo Victor Company.

Carl E. Hall (M), Aerophysics Specialist, Aerophysics Development Corporation. Formerly, Preliminary Design Engineer, Pastushin Aviation Corporation.

Roscoe C. Hayes, Jr. (TM), Associate Aircraft Engineer, Georgia Division, Lockheed Aircraft Corporation. Formerly, Material Review Engineer, Temco Aircraft Corporation.

Earl R. Hinz (M), Research Group Engineer, Head, Stability and Control Group, Ryan Aeronautical Company. Formerly, Aerodynamics Engineer, Ryan.

Philip M. Klauber (M), Chief Administrative Engineer, Solar Aircraft Company, San Diego. Formerly, Director of Public Relations, Solar.

C. R. Lemonier (AF), Head, Plastics Department, Fairchild Guided Missiles Division, Fairchild Engine and Airplane Corporation. Formerly, Chief, Molded Products Division, Fairchild Guided Missiles Division.

D. B. (Ted) Martin (AF), Manager, Pilotless Aircraft Sales, Boeing Airplane Company. Formerly, Manager, Military Sales, Boeing.

Philip R. Marvin (M), now Economist, American Viscose Corporation.

Walter F. McGinty (AF), Sales Representative, San Diego Territory, Parker Aircraft Company. Formerly, Chief Engineer, Transco Products, Inc.

William J. Pattison (M), Director—Military Relations and Foreign Operations, The Garrett Corporation. Formerly, Director—Sales and Service, AiResearch Manufacturing Company, Division of The Garrett Corporation.

Dr. Richard W. Porter (M), Consultant—Communication and Control, Engineering Services Division, General Electric Company, New York. Formerly, General Manager, Guided Missiles Department, G-E, Schenectady, N.Y.

Richard P. Reul (M), Preliminary Design Engineer, Radioplane Company. Formerly, Supervisor, Flight Test Data Analysis, Douglas Aircraft Company, Inc.

Lyman A. Bullard, Jr., AFIAS, was recently appointed Manager of the newly established Flight Safety Products Department of Greer Hydraulics, Inc. Mr. Bullard was formerly Director of Spares for Republic Aviation Corporation.

Two of Solar Aircraft Company's top engineers have been named to new positions. *Left*, Paul A. Pitt, MIAS, formerly Chief Engineer of the Development Engineering Division, is now Chief Engineer of Solar's new Engineering Division, a combination of the former Design Engineering and Development Engineering divisions. William C. Heath, AFIAS, who was Chief Engineer of the Design Engineering Division, is now Executive Engineer—Marketing and heads the engineering staff of the company's Sales Division.

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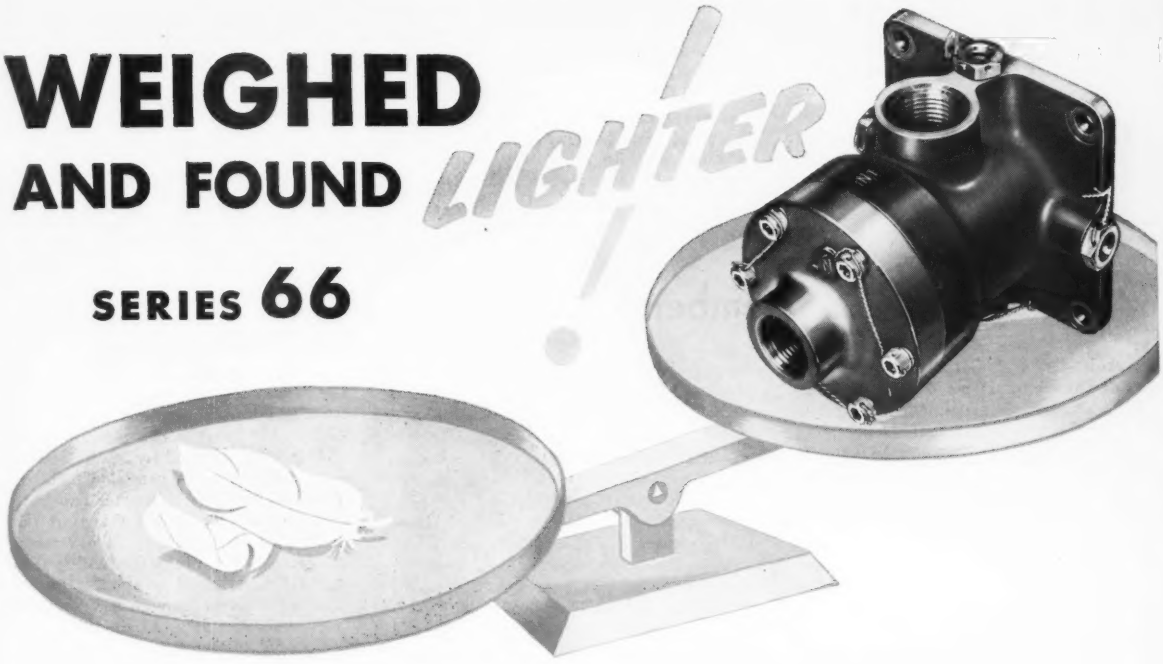

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Ray F. Siewert (TM), Second Lieutenant, USA, Extended Active Duty, Corps of Engineers, U.S. Army, Fort Belvoir, Virginia. Formerly, Associate Engineer, The Glenn L. Martin Company.

David B. Thurston (AF), President, Colonial Aircraft Corporation. Formerly, Supervisor—Guided Missile Design and Production, Grumman Aircraft Engineering Corporation.

Sidney H. Webster (M), Manager—West Coast (except State of Washington), Los Angeles Office, Jack & Heintz, Inc. Formerly, Manager—Northeast District, New York Office, Jack & Heintz.

Henryk K. Zienkiewicz (TM), Lecturer, Fluid Motion Laboratory, University of Manchester, England. Formerly, Aerodynamicist, Navigational Project Division, The English Electric Company, Ltd., England.

Corporate Member News

• **Aerojet-General Corporation, Subsidiary of The General Tire & Rubber Company. . .**Additional armament plant facilities for the new Armament Department have been completed at the 14,000-acre plant site near Sacramento, Calif.

• **Aeroquip Corporation. . .**Through a recently formed Canadian subsidiary—Prenco-Aeroquip Ltd.—Aeroquip has acquired all of the assets of Prenco Progress & Engineering Corporation of Toronto, Canada, which relate to its flexible hose lines and self-sealing couplings business, including machinery, equipment, inventory, and unfilled orders. Prenco is a former licensee of Aeroquip. Prenco-Aeroquip is occupying temporarily the same quarters as Prenco, continuing without interruption the latter's operations in the fields of flexible hose lines and self-sealing couplings.

• **Aircraft Radio Corporation. . .**Orion Industries, Inc., of Richmond, Va., developers and manufacturers of a line of aircraft flight instruments and navigation computers, was acquired late in January by Aircraft Radio. The transaction involved Orion's products, its research and development facilities, and its personnel. Robert Haskins, MIAS, President of Orion, has joined ARC's research and development staff.

• **Allison Division, General Motors Corporation. . .**Model 501-D10, a commercial version of the T56 turboprop engine, is being offered to U.S. air lines and air-frame manufacturers. This engine, which develops 3,750 equivalent shaft horsepower, has a reported power-to-weight ratio of more than 2.3 to 1. The Model 501 is said to exceed the performance of any other turboprop engine available anywhere today.

• **Aluminum Company of America. . .**A forging press weighing almost 4,000,000 lbs. and capable of applying 8,000 tons of pressure is now operating at Alcoa's Cleveland (Ohio) works. This press, an important production tool for aircraft forgings, was supplied to Alcoa under a lease arrangement with the U.S. Air Force.

• **American Non-Gran Bronze Company. . .**The company's operations have been widened to include the contract machining of parts made of carbon steel and stainless steel alloys for use in jet aircraft.

Bell Aircraft Corporation recently introduced its new vertical take-off and landing aircraft that incorporates a glider fuselage, a commercial light-plane wing, and a helicopter landing gear. Bell's VTOL airplane is powered by two J-44 turbojet engines, built by Fairchild Engine and Airplane Corporation's Fairchild Engine Division and loaned to Bell by the U.S. Air Force. For take-offs and landings, the two jet engines are in a vertical position, as shown here. For forward flight, they are rotated 90° to a horizontal position, and the plane is flown forward like a conventional fixed-wing aircraft. This one-place test vehicle weighs about 2,000 lbs., is 21 ft. long, and has a wing span of 26 ft.

• **Avien, Inc. . . .**A 16-page two-color brochure entitled *Thrust* has been published by Avien. This new publication describes the company's facilities for research, development, and design of instrumentation for aircraft and guided missiles. . . . Another two-color 16-page brochure, entitled *Precision Defined*, describes facilities available for subcontract manufacturing. This illustrated publication shows production facilities that, the company says, are adapted to a wide range of electrical, electronic, and mechanical equipment in the instrument and other fields that require precision manufacturing techniques.

• **Bell Aircraft Corporation. . .**A hydraulic boost control has been incorporated into the Model 47H executive helicopter and is now standard equipment on the Model 47G utility craft. The primary purpose of this CAA-certified hydraulic assistance is to add a smooth precision feel to the cyclic stick. The helicopter can be controlled manually should this unit fail in flight. The hydraulic cyclic controls consist primarily of a tank containing about 1 qt. of hydraulic oil, a small pump that circulates the oil through the system four times a minute at approximately 250 lbs. per sq. in. of pressure, and two double-acting hydraulic cylinders—1 in. in diameter and 3 in. in stroke—which apply about 100 lbs. force to the fore-and-aft and lateral cyclic controls as directed by the pilot.

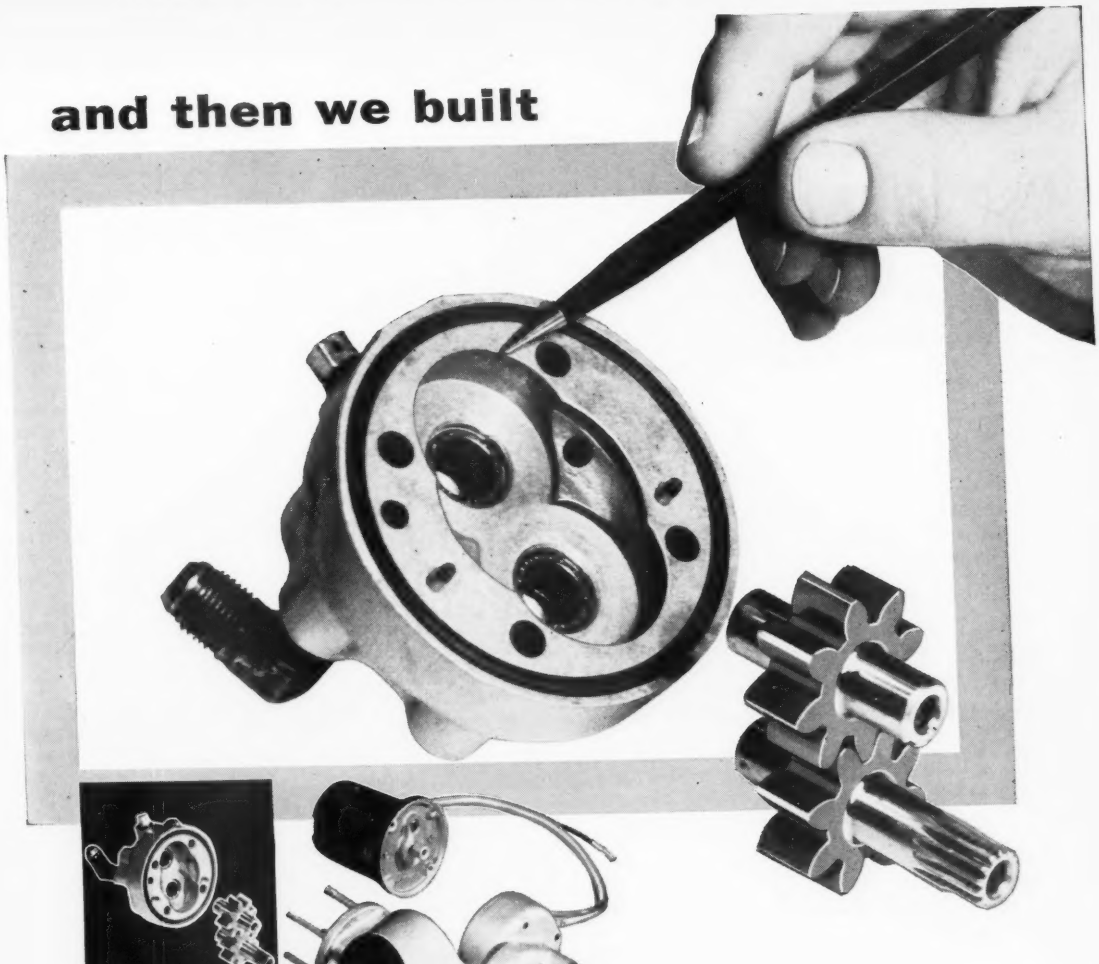
• **Douglas Aircraft Company, Inc. . . .**A new instrument panel that presents data in a pictorial form, instead of through conventional dials, has been disclosed by the U.S. Navy. This project, for which Douglas is the prime contractor and coordinator for the aviation instrument manufacturers engaged in the program, involves the use of a flat transparent television picture tube. This tube makes possible the graphic presentation of data and was developed as a proprietary item by Willys Motors, Inc. Based on research in human engineering, the new panel is a development of a long-range instrument program of the Office of Naval Research and the Bureau of Aeronautics. The Navy expects the first experimental plane using this system to be flown about 1958. The Douglas El Segundo Engineering Department produced the panel.

• **The Garrett Corporation. . .**John K. Northrop, IAS Fellow and Past-President, was recently elected a member of Garrett's Board of Directors. Mr. Northrop, who retired in 1952 from the presidency of Northrop Aircraft, Inc., has been associated with Garrett in a consultant capacity.

• **General Electric Company. . .**A new 4-page publication, designated GEA-6203, describes the testing facilities at G-E's Specialty Component Motor Department. This bulletin is available from the company's Schenectady office.

• **G. M. Giannini & Company, Inc. . . .**A high-performance Rate Gyro, Model 36128, suitable for use in aircraft and missile control or telemetering, has been announced. Enclosed in a hermetically sealed oil-filled case, the gyro is maintained at a uniform temperature by means of internal thermostatically controlled heating elements to make possible constant damping

and then we built

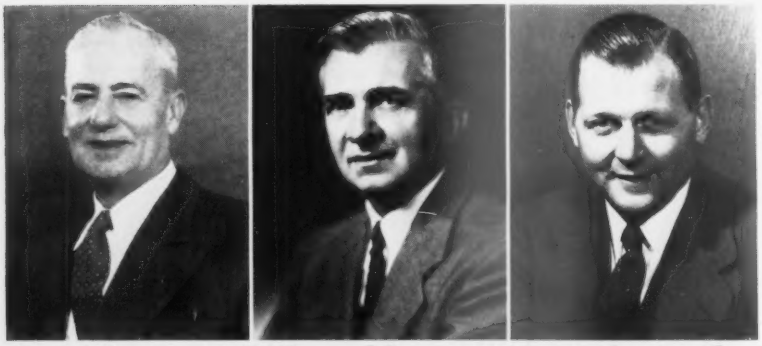


. . . a propeller pitch control transmission assembly for Beech Aircraft Corporation.

In order for the hydraulic motor to function properly, the tolerances on practically all of the dimensions had to be held to within .0001″ or .0002″ for squareness, parallelism and concentricity.

INDIANA GEAR

INDIANA GEAR WORKS, INC. · INDIANAPOLIS, INDIANA



Preston R. Bassett (*center*), IAS Honorary Fellow, retired last January as President of Sperry Gyroscope Company Division of The Sperry Corporation. Mr. Bassett continues, however, as a Vice-President of The Sperry Corporation. Succeeding him as President of Sperry Gyroscope is Charles M. Green (*left*) who was Executive Vice-President and General Manager. Carl G. Holschuh (*right*), MIAS, was appointed Executive Vice-President and General Manager. Mr. Holschuh had been Vice-President and Assistant General Manager.

ratio over a wide ambient temperature range. Model 36128 Rate Gyro weighs less than 1.5 lbs. and measures 2 in. in diameter and 2.68 in. in length. It is also available with induction potentiometer output (Model 36628).

• **Jack & Heintz, Inc . . . .** Two new three-phase high-altitude inverters (models F-138-1 and F-148-1) are being produced for the U.S. Navy and other military and commercial aircraft. These new inverters (motor-generators) will deliver full-rated load at altitudes to 50,000 ft. and at least half-rated load as high as 65,000 ft.

• **Kearfott Company, Inc., Division of General Precision Equipment Corporation. . .** A new corrosion-resistant synchro has been made available by Kearfott with leads or terminals, single- or double-ended shafts, 26- or 115-volt excitation, and/or high or low impedance. Designated as the R900 series, these Size 11 Synchros are available for all functions including transmitters, control transformers, receivers, resolvers, and differentials. Torque receivers are available, with hollow shafts for coaxial mounting in certain indicator applications. This new series is dimensionally and electrically interchangeable with the Kearfott R200 series Size 11 Synchros.

• **Lear Incorporated. . .** An improved attitude indicator, developed by Lear and ARDC's Wright Air Development Center, has been put into production. The new indicators, designated the MM-1 for the 5-in. face model and MM-2 for the 3-in. face model, combine several features, including a type of presentation or display which is "strikingly different" and which is said to permit easy reading at all pitch attitudes except vertical flight. The basic gyro mechanism in this instrument incorporates the so-called pitch-bank compensator for turn error. The attitude indicator is adaptable to an inclined instrument panel. . . .A new autopilot, designated the L-10, has been designed for supersonic aircraft. The L-10 has a lighter overall weight than its predecessor, the F-5. . . .A brochure on the Lear Arcon (Automatic Rudder Control) has been put out by the LearCal Division. . . .A 26-page booklet, recently published by Lear, describes the company's Research and Development Division.

• **Northrop Aircraft, Inc. . . .** Robert R. Miller, formerly Assistant to the President, was elected a Vice-President and Executive Assistant to the President. Mr. Miller, who joined Northrop in 1951, is also a Director of Northrop's subsidiary, Radioplane Company.

• **Northrop Aircraft, Inc., and Radioplane Company. . .** Special facilities in the American Motors plant at El Segundo, Calif., have been taken over by Northrop and its subsidiary, Radioplane. These new quarters are being used for a top-priority pilotless aircraft project under Radioplane's overall responsibility. A design team of 60 scientists and technicians from the two companies has moved into the new facility.

• **Pesco Products Division, Borg-Warner Corporation. . .** Robert G. Hess has been appointed Vice-President—Operations of Pesco Products. He was formerly General Manager of New York Air Brake Company's Watertown (N.Y.) Division.

• **Piasecki Helicopter Corporation. . .** William Davey has been elected Vice-President of Manufacturing. Mr. Davey joined the Piasecki organization in December, 1951, as Assistant Manufacturing Manager. He was named Director of Manufacturing in February, 1953.

• **Radioplane Company. . .** A. W. Callam and W. P. Patterson have been elected Assistant Vice-Presidents of Radioplane. Mr. Callam's area of responsibility is military relations, and Mr. Patterson's is engineering.

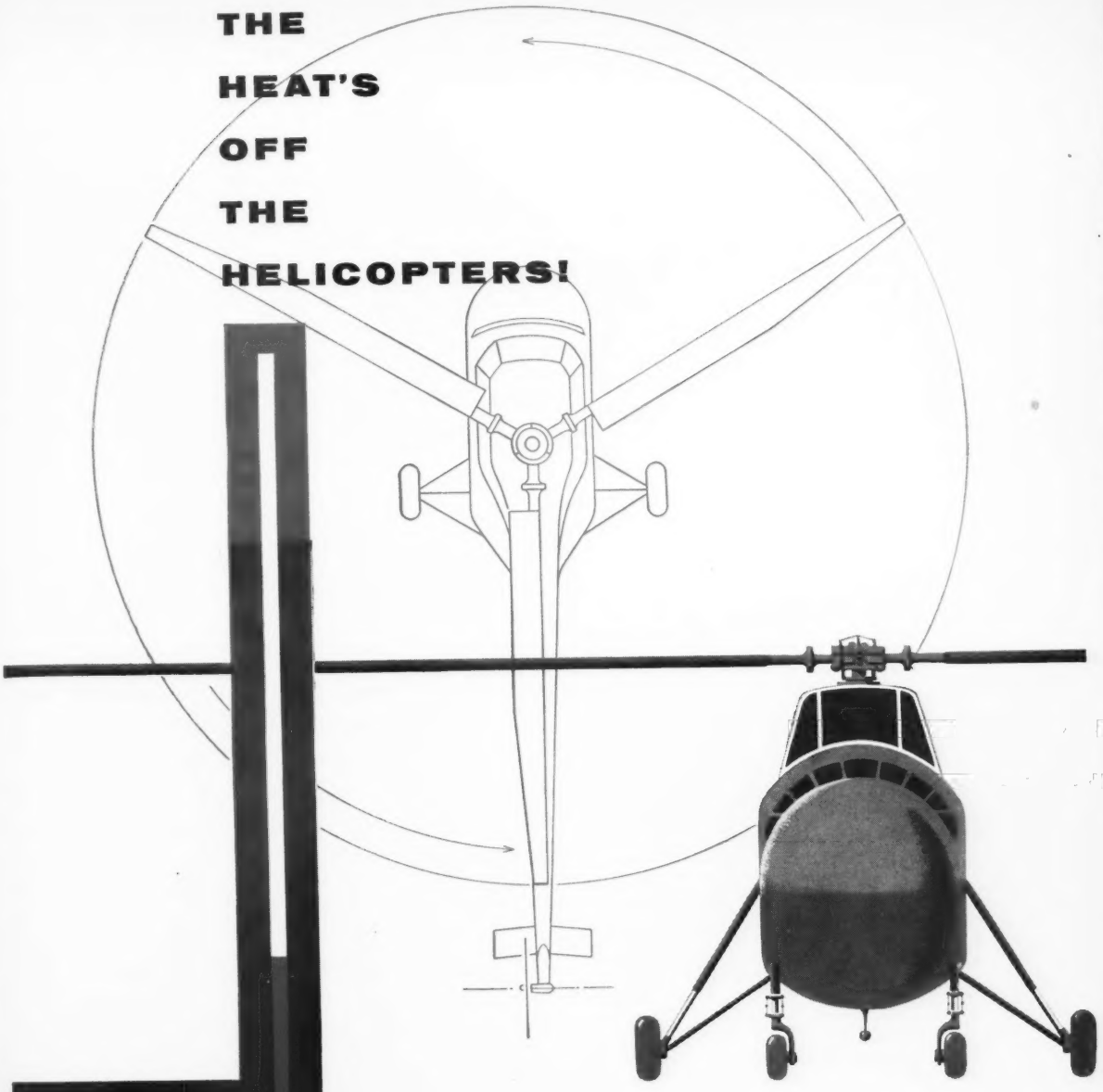
• **Republic Aviation Corporation. . .** A plastic cover has been developed to protect jet engines from foreign matter during aircraft production. Made of electronically sealed vinyl plastic sheeting, the cover is inflated into place in the nose of the engine as soon as it is unpacked and removed from its shipping crate. It provides an immediate tight seal that remains in place until the engine is run up on inspection of the finished aircraft. This cover has no metal or other hard parts, and should it be inadvertently sucked into the engine, the material can pass through without damaging rotor blades or other parts of the engine.

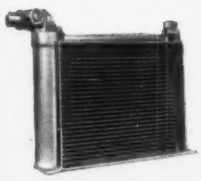
• **Ryan Aeronautical Company. . .** A jet-powered vertical-take-off aircraft is being developed by Ryan under a USAF contract.

• **Thompson Products, Inc. . . .** Plans for the construction of a $5,000,000 engineering study center have been disclosed. This research center, to be built on a site just east of the Tapco Plant at 23555 Euclid Ave., Euclid, Ohio, is intended to facilitate the development of new products, processes, and materials, and will make it possible for the company to consolidate a number of its central staff engineering and research activities now in various locations at the Tapco Plant. Present plans call for the ultimate construction of five buildings, grouped as a compound and connected by covered walks. Construction on the first two units—the Automotive Development Laboratory and the Chemical

Bell Aircraft Corporation's XV-3 convertiplane that features a tilting-rotor design was developed for the U.S. Army under a joint Army-Air Force contract. During take-offs, landings, and low-speed flight, the XV-3 operates like a helicopter with the rotor mast axis in a vertical position. However, after the basic speed is reached, the masts are tilted forward through a 90° arc until they are horizontal and act as propellers. During this conversion process, which requires 10–15 sec., the lift load is transferred from the rotors to the wing. As an airplane, the XV-3 convertiplane has a speed of more than 175 m.p.h. The aircraft measures 30 ft. in length and 13 ft. in height and has a wing span of 30 ft.

THE HEAT'S OFF THE HELICOPTERS!





A struggling infant a few short years ago—*now the 'copter has won everyone's confidence!* And Harrison oil coolers helped them make the grade—enabled them to fly faster . . . farther . . . with bigger, more profitable payloads. Harrison's unexcelled research facilities deliver the designs that save space and weight. In fact, Harrison is *always* looking for new ways to make aircraft heat exchangers of all kinds lighter, more dependable, more durable than ever! If you have a cooling problem, look to Harrison for the answer!

HARRISON RADIATOR DIVISION, GENERAL MOTORS CORP., LOCKPORT, N. Y.

HARRISON

TEMPERATURES MADE TO ORDER

and Metallurgical Laboratory—will get under way by the fall of 1955 and will cost an estimated $2,000,000. The remaining three units—the Staff Industrial Engineering Laboratory, the New Devices Laboratory, and the Administration Building—will be erected over a period of years. Service buildings will be provided as required. It is estimated that the entire research center will be completed by the end of 1958.

• **Western Gear Works. . .**A series of high-precision high-torque T-boxes and angle drives have been announced by the company's Aviation and Electro Products Division. . . .Ronald Hinman has been named Marketing Manager, aircraft and electro products, for the company's six plants.

IAS Sections

Atlanta Section

Edith H. Lively, *Secretary*

1955 opened for the Atlanta Section with a dinner meeting held Thursday evening, January 6, at the Officers Club, Naval Air Station, Chamblee, Ga. A social hour preceded the dinner. Following the dinner, Chairman E. I. Bricker introduced special members and guests and then held a short business meeting in order to allow all the time possible for the speaker of the evening.

Program Chairman Otis Norcross introduced our guest, Dr. Adolf K. Thiel, Chief of the Technical Feasibilities Studies Office at Redstone Arsenal, the Army Ordnance Corps center for research and development of rockets and guided missiles. Dr. Thiel, a graduate of the University of Vienna, studied aeronautics there and at Darmstadt, Germany, where he earned his Ph.D. He remained at Darmstadt until 1945 as a Consultant and Contractor on guided missiles at Peenemunde. In 1946 he came to the United States under contract to the Army Ordnance Corps. He became an American citizen last year.

Dr. Thiel gave an interesting technical talk on performances of rocket-propelled vehicles. He began by stating that, although a great cloak of secrecy has been drawn over the armed forces rocket development program, it is rather obvious to most of us that the rocket is just about to outgrow its teens and become a beautiful though sometimes still moody young lady. And, as any man, whether an engineer or fishmonger, who has been involved with young ladies is aware, this is a most interesting period of development.

After discussing the various types of jet propulsion and present applications of rocket thrust, such as assisted take-off, airplane power plants, projectiles, and guided missiles, Dr. Thiel discussed the basic concepts of rocket motors and some of the problems that face the rocket designer. Among these are the cooling of the rocket chamber where temperatures of 4,000° to 5,500°F. are encountered at pressures of 300 lbs. per sq.in., proper nozzle and throat design, and in the case of liquid-propellant rockets, additional problems of control valves and feed systems are introduced. It was pointed out that the rocket turbopump systems are highly efficient as compared to turbine-air compressor-fuel pump units of an aircraft turbojet. A rocket system absorbs only about 2 per cent of the available gas energy, while the aircraft system consumes about 50 per cent of the available energy.

Examples were shown of the rocket-powered airplane, the rocket projectile, and the guided missile, with a brief discussion of the characteristics of each.

Entering into the more theoretical aspects of rocket design, Dr. Thiel developed a series of equations from the reaction and momentum principles and pointed out that a propellant-producing high-combustion temperature with low molecular weight of the combustion product seemed to be the desirable choice. However, chemical, technological, and overall system considerations modify this in that the maximum temperature in the combustion chamber is limited by two factors: (a) the disassociation reaction of the combustion gases which at temperatures beyond 5,000°F. causes increasing losses in the jet energy, and even more important (b) the heat resistance and cooling problem of the motor construction material. Also, the decrease of molecular weight of the combustion gas through proper propellant choice might not be desirable, since decreasing mass means hydrogen-rich fuel of low density, and low-density propellants increase the overall propulsion system and vehicle weight. It was pointed out that the propulsion system performance should not only be judged by thrust consideration, but overall system performance and system weight consideration have to be included when determining an optimum propulsion system.

Finally, making the assumption of a missile operating in a vacuum and under constant gravitational forces and starting from Newton's laws of motion, Dr. Thiel evolved a series of basic equations and parameters which he presented in the form of graphs. As a result of these graphs, he was able to show that a single-stage rocket-propelled vehicle can retain flight velocities somewhat greater than the jet exhaust velocity. The flight velocity increases as less weight is used in the vehicle structure and apparently also as less time is spent combating the pull of gravity. However, it is impossible to take advantage of both improvements simultaneously. It was also pointed out that there is a definite performance limitation for single-stage rocket vehicles which, expressed in cutoff velocity, can be given as 1.0 to 1.8 times the exhaust velocity. Taking an exhaust velocity of 8,500 ft. per sec. yields a cutoff velocity of 8,500 ft. per sec. to 15,300 ft. per sec. corresponding to ballistic ranges of about 500 to 1,500 miles where the latter figure should be considered as rather optimistic. Dr. Thiel hastened to point out that this would be a very discouraging performance outlook for our present-day, single-stage rockets, especially with regard to space travel. However, through the application of multistage rockets we can increase this performance to any desired velocity, if we are willing to pay the price for it. Dr. Thiel emphasized the fact that a rocket vehicle with a large number of stages is not always superior to a rocket vehicle with a lesser number of stages. As a matter of fact, within a certain performance region, the single-stage vehicle is superior to multistage design; then, by increasing the performance requirements, we find the two-stage design superior; then the three-stage, etc. He further pointed out that the graphs indicate the inherent shortcomings of a rocket vehicle in requiring a very large gross weight to transport a relatively small payload, particularly when high performances are desired. The solution to this problem is the well-known concept of using artificial satellites as assembly, storage, and final space launch stations. Dr. Thiel closed his discussion by pointing out that, although this would still be a tremendous engineering undertaking, it is at least in the realm of technical and economical feasibility. He emphasized that the time scale for such a development is numbered in decades rather than years and that it is clearly a challenge to the young engineer and scientist.

Following a discussion period, the meeting was adjourned.

Baltimore Section

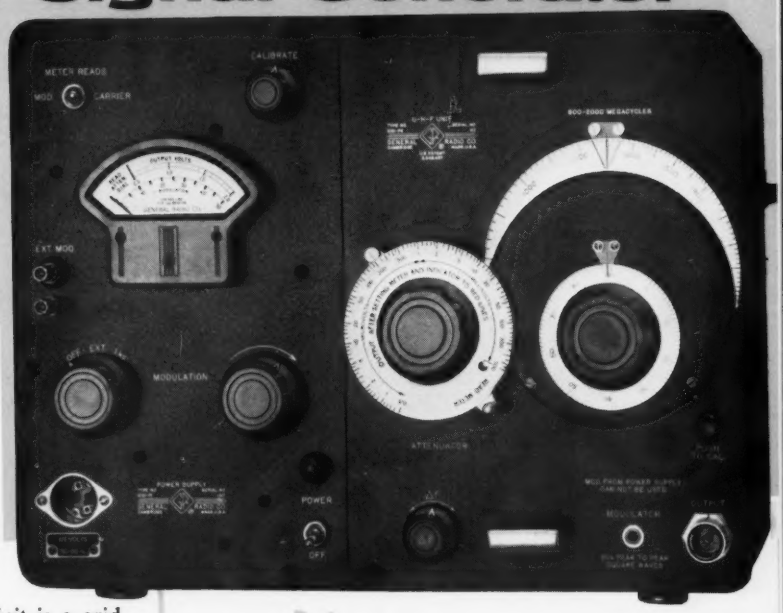
Raymond D. Blakeslee, *Secretary*

The Fifty-Fifth Meeting of the Baltimore Section of the Institute of the Aeronautical Sciences was held in Maryland Hall, The Johns Hopkins University, on Thursday, January 13, at 8:30 p.m. The meeting was attended by approximately 100 members and guests.

Chairman Herman Pusin presided. After the Secretary's report was pre-

Standard-Signal Generator

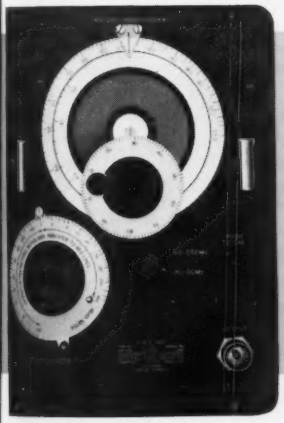
40 to 2000 Mc



The range of the popular Type 1021-A Standard-Signal Generator has been extended to 2,000 Mc with the addition of a third oscillator unit, and downward to 40 Mc with the added 40-50 Mc range of the low-frequency oscillator unit. Now, the complete frequency range from 40 to 2,000 Mc is covered by one power supply and three oscillator units with frequency ranges of 40-250, 250-920, and 900-2,000 Mc, respectively.

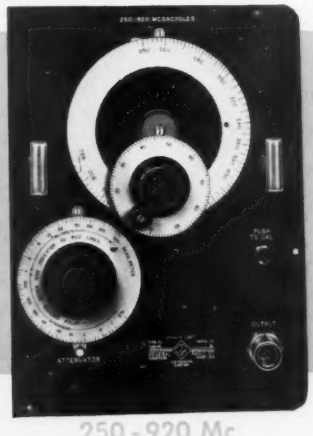
The new Type 1021-P4 900-2,000 Mc Unit is a grid separation triode oscillator using a Type 5675 uhf pencil tube. It delivers relatively high output at uhf . . . is stable and well shielded . . . has provision for square-wave modulation . . . and is low in cost for a high-performance signal source. Line sections with sliding contacts are used to tune plate and cathode— tuning is exceptionally smooth. The instrument is remarkably free of noise modulation caused by microphonics and vibrations.

Additional Oscillator Units



40 - 250 Mc

Type 1021-P3B now has added 40-50 Mc range for television i-f measurements, v-h-f receiver and amplifier development.



250 - 920 Mc

Type 1021-P2 is a convenient, well-shielded source of power for bridge and slotted line measurements and u-h-f television work.

NEW

Type 1021-P4 Oscillator Unit

SPECIFICATIONS

Frequency Range 900-2000 Mc

Frequency Calibration Accuracy Large direct-reading dial with slow motion drive calibrated to 1% over 200°

Incremental Frequency Control Variable resistor in grid circuit provides small frequency adjustments.

Frequency Drift Under 0.1% per day

Output Voltage Continuously adjustable from 0.5 μv to 1.0 volt open circuit.

Output Impedance 50 ohms $\pm$10%

Output Meter Output voltage indications accurate to better than 20% — meter circuit can be calibrated in terms of accurately known 60-Cycle voltage.

Modulation Provision Square-wave modulation from 100-5,000 cycles from external modulator.

Leakage Stray fields and residual output voltage cannot be detected with receiver having 2 μv sensitivity.

Heater Voltage Rectified To reduce modulation by power frequency.

Inexpensive Tube Replacement Only $15.20

Frequency	Standard-Signal Generator		Oscillator Unit	Power Supply
40— 250 Mc	1021—AV, $595		1021—P3B, $400	and 1021—P1, $195
250— 920 Mc	1021—AU, $615	consists of	1021—P2, $420	
900—2000 Mc	1021—AW, $845		1021—P4, $650	

GENERAL RADIO Company

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40 Years of Pioneering
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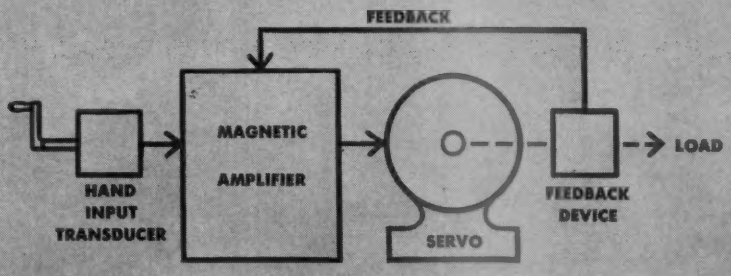
Magnetic Amplifier SERVO SYSTEMS
In the Horsepower Range



The task called for a rugged, reliable drive of a motor which would deliver up to four horsepower on acceleration, and at least 1½ horsepower continuously. Maintenance requirements to be at a minimum. The drive must be able to stand high shock and operate under several G's. It must operate in temperatures from –65° to 165°F.

Ford engineers developed such a drive in a magnetic amplifier servo system. It could be made for position control or rate control, and it operated smoothly and accurately under an unbalanced load condition. The gain or current-output/current-input (with motor stalled) = 60,000; with a maximum output of over 90 amps.

This is typical of the solution of engineering problems in the field of servomechanisms by the Ford Instrument Company. Should you have a problem such a solution may answer for you, write and indicate your needs. Ford Instrument Company's forty years of experience in developing, designing and manufacturing special devices in the field of automatic control will help you find the answer.

FORD INSTRUMENT COMPANY
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sented, Mr. Pusin introduced two of our national officers who were in attendance, S. Paul Johnston, IAS Director, and Robert R. Dexter, IAS Secretary. He then announced several scheduled meetings of interest to the membership.

The speaker of the evening was Lt. Gen. Thomas S. Power, USAF, Commander, Air Research and Development Command. General Power spoke on "The Air Research and Development Team."

He discussed the importance of the relationship of the Air Research and Development Command with science and industry in maintaining qualitative superiority for the United States Air Force in the face of a quantitative deficiency.

The General emphasized the importance of teamwork between the armed forces, science and industry. Inasmuch as the United States is outnumbered by the enemy and cannot meet the quantity, the quality must be superior. Equipment and armament superiority must be maintained, and it is the purpose of ARDC to see that this mission is carried out.

In order to develop the most effective weapons, it is necessary that the weapon system concept become a joint effort between the military and industry. Weapon systems must be timed to phase in properly, must keep a budget balance, and have controlled schedules. This effort is monitored by ARDC, while USAF headquarters makes the final decisions.

With the advent of the revolutionary H-bomb, immediate action for the production of operational equipment became necessary. Although funds are limited, and always critical, new techniques and production methods must be developed with the aid of science and industry.

The time and cost of weapon system proposals become most important when considering the fundamental changes taking place and the limitations of the budgets. These factors require that the number of equipment and weapon systems be reduced without loss of overall effectiveness.

ARDC is the organization responsible for coordinating the tremendous development program required for the national defense, which is the concern of industry as well as the military.

General Power closed his talk by stating that ARDC will continue to strive for further cooperation between the members of the team—science, industry, and the military—in the technological race.

Following General Power's talk, a film on Air Force research and development projects was shown. At the conclusion of the film, the meeting was adjourned.

LORD DYNAFOCAL MOUNTING

MR-36M

FOR R-2800C ENGINES

LORD FACTS ABOUT VIBRATION

MAINTENANCE MEMO:

To Operators of Convair 240's and 340's, Douglas DC6 Series, Martin 404's, and Military Aircraft using R-2800C engines -

Change over to the new LORD MR-36M Dynafocal Engine Mounting for MORE PAYLOAD, LOWER MAINTENANCE COSTS, BETTER PERFORMANCE.

PROVEN DURABILITY—The MR-36M has proved its durability in extensive service on commercial and military airliners, thus reducing maintenance and operating costs.

LIGHTER WEIGHT—The MR-36M is the lightest available production mounting for R-2800C engines. It provides a weight saving of nine pounds per engine over our previous light weight design.

GREATER STRENGTH—Design and construction features of the MR-36M provide greater strength than any previous designs for this mounting.

INTERCHANGEABILITY—The MR-36M is completely interchangeable without rework on aircraft using R-2800C engines. It provides all physical dimensions and vibration characteristics of heavier mountings now in use.

LORD MANUFACTURING COMPANY, ERIE, PA.

LORD BONDED RUBBER

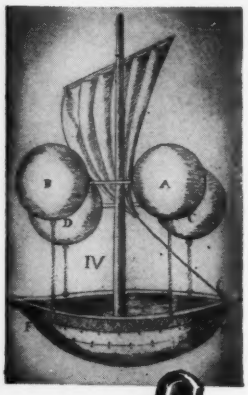
DESIGNERS AND PRODUCERS OF BONDED RUBBER PRODUCTS SINCE 1924

DESIGN FOR FLYING BOAT

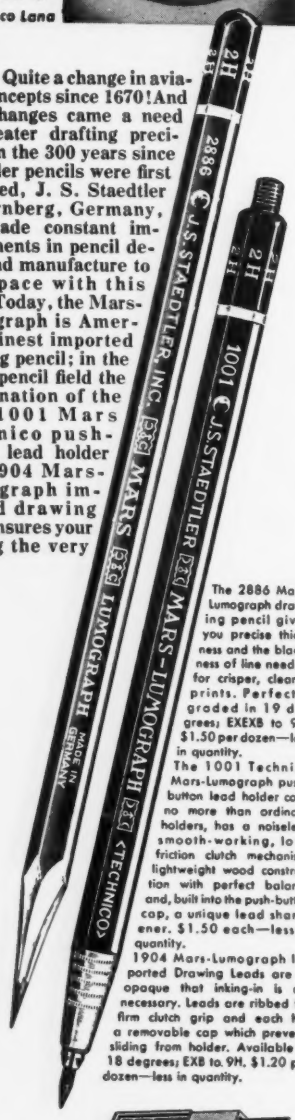
WITH VACUUM-GLOBE LIFT

by 1670

Francesco Lana



Quite a change in aviation concepts since 1670! And with changes came a need for greater drafting precision. In the 300 years since Staedtler pencils were first produced, J. S. Staedtler of Nurnberg, Germany, has made constant improvements in pencil design and manufacture to keep pace with this need. Today, the Mars-Lumograph is America's finest imported drawing pencil; in the clutch pencil field the combination of the new 1001 Mars Technico push-button lead holder and 1904 Mars-Lumograph imported drawing leads insures your having the very best.



The 2886 Mars-Lumograph drawing pencil gives you precise thickness and the blackness of line needed for crisper, cleaner prints. Perfectly graded in 19 degrees; EXEXB to 9H. $1.50 per dozen—less in quantity.

The 1001 Technico Mars-Lumograph push-button lead holder costs no more than ordinary holders, has a noiseless, smooth-working, low-friction clutch mechanism, lightweight wood construction with perfect balance and, built into the push-button cap, a unique lead sharpener. $1.50 each—less in quantity.

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Dayton Section

Gunther R. Graetzer, *Secretary*

The January 13 meeting was held at Cordell's Supper Club, Fairborn, Ohio, with an attendance of 98 engineers. The speakers, Paul A. Simmons, Jr., and Paul E. Haueter, discussed helicopters and convertiplanes, respectively.

Paul A. Simmons, Chief of the Rotary Wing Branch, Wright-Patterson Air Force Base, stated that, despite the encouraging success of the helicopter in the last decade, there has been increasing interest and effort in recent years in other aircraft types involving rotary-wing principles. One reason for this is the recognized limited speed potential of the helicopter. Inherent conditions of operation of a helicopter rotor involve asymmetrical flow over the rotor disc and the need to maintain lift moment symmetry. These conditions lead to two rather fundamental limits of retreating blade stall and Mach Number effects on the advancing blade. These factors were examined in relation to major rotor design variables, such as blade airfoil, disc loading, solidity, and tip speed. Usable values of these variables seem to indicate a practical helicopter speed limitation on the order of 150 knots. Other factors such as horsepower, vibration, stresses, and advance ratio, which are closely related to these two more fundamental limits in any practical design problem, were briefly discussed. A movie showed the motion of a blade during its cycle; the camera for this movie was mounted on the rotating hub and took pictures along the blade length.

The speed limitation of the helicopter led to the development of the convertiplane, which was discussed by Paul E. Haueter, Chief, Convertiplane Weapons System office, WADC. The definition of a convertiplane type of aircraft is still confused. It would appear that for the time being the following definition best fits those aircraft that are being developed and are generally considered to be true convertiplanes: aircraft capable of duplicating all helicopter flight regimes and, by either mechanical or aerodynamic conversion, removing such limitations to permit the aircraft to have a speed and range capability approaching fixed-wing aircraft.

Although the word convertiplane is relatively new, some investigations date back to World War I. The Air Force-Army convertiplane design competition in 1950 represents the greatest effort to develop this type of aircraft to date.

There are essentially three basic convertiplane configurations at this time: unloaded rotor type, tilting rotor type, and retractable rotor type. Obviously, there are a great number of variations in each of these configurations. After

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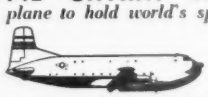

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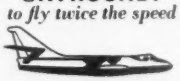

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necessary development, the convertiplane should be able to perform many unique and valuable missions both in a military and civilian capacity; however, it does not appear that it will replace either the helicopter or fixed-wing aircraft.

The Chairman, George J. McTigue, closed the lively discussion and the meeting at 9:45 p.m.

Hagerstown Section

Andrew Pickens, *Secretary-Treasurer*

The January 18 meeting of the Hagerstown Section was conducted in the Packet Room of the Terrace Restaurant. Fifty-two members and guests attended.

The program, a discussion of the General Engineering Department, was opened by Adam Shostak who introduced Roy W. Lessard, Fairchild Chief Production Engineer. As Chairman of a panel, Mr. Lessard presented an outline of the organization and purpose of General Engineering and introduced the various panel members, each of whom spoke briefly on some phase of the subject. The speakers and topics were: R. D. Gilson, "Lofting and Design"; J. A. Neilson, "Structures"; C. F. Comstock, "Weights Group"; E. H. Kramer, "Flutter and Vibrations"; J. N. Marsden, "Engineering Test Laboratory"; R. H. Ziegenfuss, "Liaison Engineering"; J. M. Hingley, "Specifications Section"; and G. A. Evans, "Engineering Services."

The meeting was concluded with the serving of refreshments and the showing of a color film on the Boeing 707 airplane.

Hampton Roads Section

Richard E. Kuhn
Corresponding Secretary

On January 15 the Hampton Roads Section of the IAS met jointly with the local Engineers Club in the Activities Building of the NACA Langley Aeronautical Laboratory. IAS Chairman Emanuel Boxer introduced the speakers, J. C. Owen, John Harper, and E. Conklin, to approximately 100 members and guests.

Mr. Owen, Chief Engineer of Lear's Grand Rapids Division, has had 15 years' experience in automatic pilot and mechanism design. He received his early training at the U.S. Naval Academy and was Senior Engineer in charge of flight control systems with the Eclipse Division of Bendix Aviation Corporation before becoming associated with Lear. The speaker was therefore well qualified to talk on "Integrated Flight Control System." He started with a historical review of the development of the airplane toward the use of automatic controls. Today, it takes about 10 lbs. of airplane for 1 lb. of automatic control. Since the individual automatic controls add up to a lot of weight, an integrated flight control system is required. Lear, Mr. Owen said, has developed an integrated flight control system that weighs 179 lbs. as compared with 238 lbs. required for the individual systems.

John Harper, Engineering Test Pilot for Lear, has had 4 years' experience as a pilot for the U.S. Navy and served as test pilot at the NACA Langley Laboratory from 1948–1953. Mr. Harper, who was Section Chairman of the Hampton Roads Section of the IAS in 1952, introduced a motion picture on the Lear F-5 automatic pilot. The picture was made to indoctrinate Air Force pilots in the use of the F-5 autopilot system.

Mr. Conklin, Sales Manager of commercial autopilots for Lear, described a typical demonstration flight.

After the meeting, the members and guests stayed for refreshments served by the Section.

This candid shot of the Los Angeles Section's January 20 dinner meeting shows some of the 400 persons who gathered to hear Lloyd T. Goodmanson, of Boeing Airplane Company, speak on the Boeing 707.

Indianapolis Section

Paul F. Ferreira, Jr., *Secretary*

The third meeting of the Indianapolis Section was held on January 11 at the Allison Division of General Motors Corporation. About 175 IAS members and guests were treated to an excellent dinner.

The dinner was followed by a short business meeting. After greetings by Chairman E. P. Howard, the chairmen of the various committees were introduced. Heading the Constitution Committee is Dr. Paul E. Stanley. W. R. Haney heads the Meetings Committee, while R. E. Saff and Phil Bright head the Publicity and Membership committees, respectively. The future meetings were also announced: March 8, April 12, and May 24.

The host at the Powerama exhibit, George J. Clingman, was introduced. Before we were taken on a tour of Allison's Powerama, a colored movie, *Theory of Jet Propulsion*, was shown.

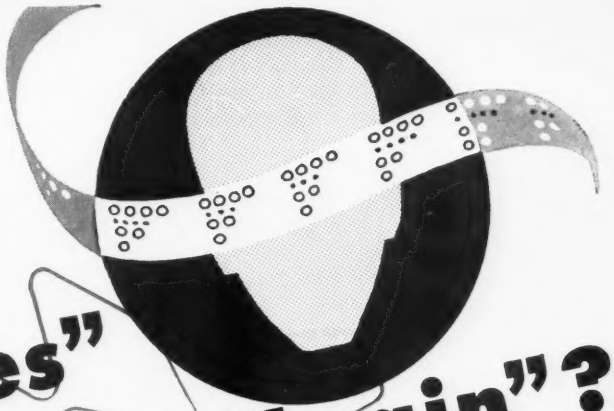
In attendance from Purdue University's IAS Student Branch were about 90 students and ten faculty members. This represents 91 per cent of the growing Student Branch, which now consists of 115 members.

Los Angeles Section

Joseph W. Wechsler, *Secretary*

The January 20 dinner meeting of the Los Angeles Section was devoted to the topic of jet transports. The principal speaker was Lloyd T. Goodmanson, Project Engineer, Jet Transport Prototype, Boeing Airplane Company, who spoke on "The Jet Transport Prototype—The Starting Point of a New Program." Prepared comment was given by Richard S. Shevell, Assistant Supervisor—Aerodynamics, at Douglas (Santa Monica), and Jim Hong, Aerodynamics Division Engineer at Lockheed. Presiding at the meeting, which attracted 400 members and guests, was Warren Dickinson, Section Chairman, and Ray Kelly, Superintendent of Technical Developments, United Air Lines, was Guest Chairman.

The speaker first described the background of the jet tanker/transport project at Boeing. Design studies had been made since 1950 on both turboprop and turbojet configurations; early in 1952 the company decided that there was a definite need for a jet tanker, and that such a craft would have the basic design characteristics for an air liner or a cargo transport. The project was officially formed on May 20, 1952, and design ob-



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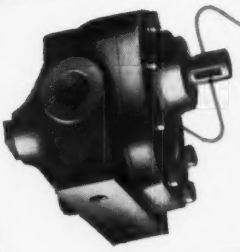

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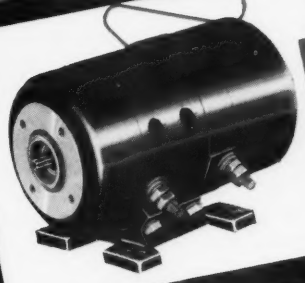

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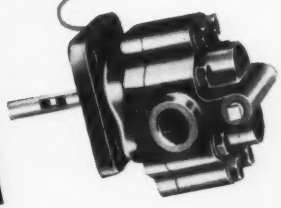

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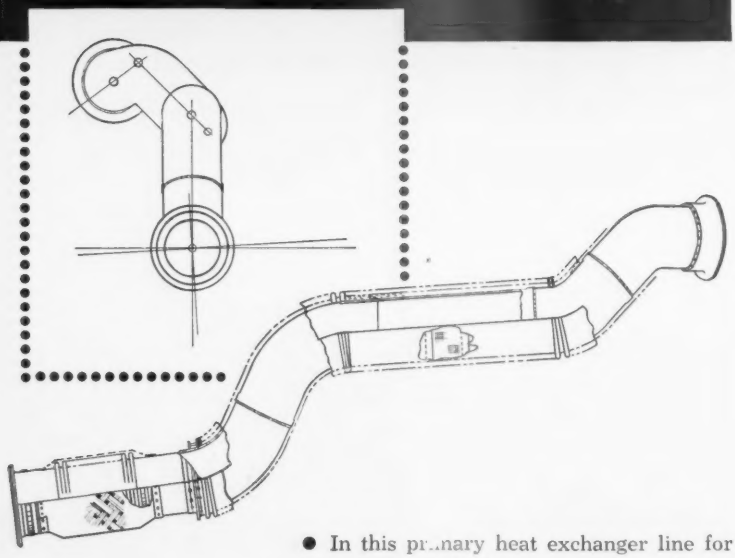

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jectives were developed at the group engineer level. These objectives called for a basically conventional aircraft that would meet anticipated tanker requirements for fuel transfer and formating capabilities as well as being versatile in its range of operations. Serviceability and ease of maintenance were stressed, as were safety and simplicity. The prototype was to be designed with provisions for production, and its construction was completed in May, 1954.

Mr. Goodmanson then discussed the value of having a prototype in being before production is initiated. He cited the two minor accidents which the prototype has had—a brake failure and a collapse of the left main landing gear—and showed how each deficiency was corrected without great expense or redesign efforts, because it was encountered in the prototype. He also mentioned an incident where a disagreement regarding the take-off distance was resolved in less than 24 hours by flight tests with the prototype. A sound movie in color, showing the first flight of the 707, concluded the presentation.

Mr. Hong congratulated Boeing on its fine pioneering effort and pointed out some of the ways in which Lockheed agrees with them on the configuration for a jet transport. Notable among these was that the wing must be swept. This decision—surprising in its coming from Lockheed—was explained as necessary to obtain sufficient space for fuel.

Mr. Shevell also congratulated the Boeing Company for its pioneering and indicated that the DC-8 would have a configuration basically similar to that of the 707. He then pointed out how objections raised a few years ago to jet transports—e.g., high fuel consumption, poor take-off thrust, and lack of reverse thrust, have been overcome one by one so that the jet is now economically competitive for ranges above 500 miles.

A lively question period concluded the meeting.

Edward F. Versaw
Member, Specialist Meetings Committee

Dr. Frank E. Marble, Associate Professor of Jet Propulsion at the California Institute of Technology and Chief of the Air-Fuel Combustion Section at the CalTech Jet Propulsion Laboratory, spoke on "The Mechanism of Flame Stabilization on Bluff Bodies" at a specialist meeting held on January 4. Dr. Edward E. Zukoski, Lecturer in Jet Propulsion at CalTech and Research Engineer at JPL, who carried out much of the work discussed in the paper, assisted Dr. Marble in the presentation. Attendance was approximately 40.

The principal contribution of Dr. Marble's work in this field was his recognition of the strong dependence of the flame-stabilization process on Reyn-

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Panel members at the December 1 meeting of the St. Louis Section are shown during a discussion of the subject "Propulsion Systems for Supersonic Aircraft." Seated from *left to right* are: Section Chairman E. M. Flesh; E. F. Pierce; W. K. Hawkins; Col. N. C. Appold, Moderator; R. Hall; and P. Kappas.

olds Number. As a result, he has been able to reduce the large disparity among the results of various investigators in this field. This was illustrated by a group of slides which concluded the talk.

Edward F. Versaw
Member, Field Trips Committee

Seventy-five members of the Los Angeles Section inspected the facilities of the Swedlow Plastics Company in Los Angeles the evening of Thursday, January 6.

The shop tour followed the production of transparent aircraft enclosures and the manufacture of intermediate pressure laminates. Representative examples of the company's many items of manufacture as well as numerous products of its research laboratory were on display.

At the conclusion of the tour, the visitors were divided into two groups, according to individual interest. About 90 per cent chose Fiberglas laminates; the others were interested in transparent enclosures. Each group was addressed by a specialist in the field who also answered questions about the shop tour.

Dr. Morris Feigen
Member, Specialist Meetings Committee

At a confidential specialist meeting of the Los Angeles Section held on January 17, Dr. Adam T. Zahorski, Chief of the Structures Division of Aerodynamics Development Corporation, spoke on "Heterogeneous Fuselage Construction for High-Speed Missiles." Attendance was approximately 250.

Dr. Zahorski presented a new philosophy of fuselage design and showed how it is possible to obtain structures lighter than those of conventional design. This new type of structure is particularly advantageous when aerodynamic heating is an important factor. The speaker also discussed the theoretical limitations of conventional monocoque construction of large fuselages. He also made theoretical comparisons using the new type of construction on existing structures and discussed some recent experiments on Fiberglas panel flutter.

Niagara Frontier Section

Clifford L. Muzzey, *Secretary*

The Niagara Frontier Section met on January 12 at the Crosby-Brounshidle Post to hear Dr. Everett T. Welmers appraise the recent rapid progress in the digital computer field in a talk entitled "Computers Come of Age." The speaker was introduced by Ronal B. Crisman, Program Chairman for the meeting.

Dr. Welmers is Chief of Dynamics at Bell Aircraft Corporation, and among his many duties he has charge of the computing facilities for Bell. Dr. Welmers is thus close to the digital computer field and the difficulties of the growth of this modern tool of engineering and science.

The speaker indicated the historical background of the computer, starting with the fingers or digits of the human hand, the abacus for more involved problems, but really taking shape with the computing engines of the Englishman, Charles Babbage, in the early nineteenth century. Babbage's machines embodied all of the fundamental concepts found in present-day computers, but the detailed technology of his day could not support his ideas by producing workable components. The wealth of techniques, largely electronic, developed in the past 15 years, has made possible the large-scale computers now in use. After a century of waiting, Babbage's ideas were implemented effectively and have been developed to a state of maturity.

Dr. Welmers set forth other aspects of the coming of age of computers. He cited the development of the major functions—input, storage, arithmetic, and output—to the point where no one process is seriously lagging behind the others and slowing down the entire machine. He also noted that the threat of reliability is being met successfully by improved tubes, transistors, and magnetic components and that the speed of handling data in digital form is now great enough to permit the rapid solving of practical problems.

Perhaps most significant of all, man is learning how to use the computer to advantage. Where it was formerly necessary to narrow down many problems and calculate solutions at a few points, it is now possible to let the machine solve the same problem with a wide variety of conditions. The investigator now chooses from a wealth of answers rather than from a wealth of questions. Special-purpose machines are also evolving and may eventually take over the jobs originally requiring high-capacity universal computers.

Finally, Dr. Welmers said that the number of digital computers in use is large and growing and that they are being accepted as mature instruments in both science and industry.

St. Louis Section

L. A. Smith, *Secretary*

Chairman E. M. Flesh opened the December 1 meeting with the introduction of the newly appointed committee chairmen. They are: F. C. Phillips, Program; J. F. Debronski, Attendance; C. U. Braun, Membership; J. F. Yardley, Professional Activities; A. A. Lambert, Civic; C. J. Kippenhan, Educational; and C. M. Forsythe, Nominating.

Chairman Flesh introduced the topic of discussion, "Propulsion Systems for Supersonic Aircraft," and then turned the meeting over to Mr. Phillips, Program Committee Chairman. Mr. Phillips introduced the panel speakers, who were E. F. Pierce, Wright Aeronautical Division, Curtiss-Wright Corporation; Russell Hall, Allison Division of General Motors Corporation; Pete Kappas, General Electric Company; and W. K. Hawkins, McDonnell Aircraft Corporation. Colonel N. C. Appold of Wright Air Development Center served as Moderator.

The discussion of the subject, "Propulsion Systems for Supersonic Aircraft," was of confidential nature, so details of the discussion cannot be reported. The meeting was thoroughly enjoyed by 160 members and guests. The panel members are to be congratulated for their presentation.

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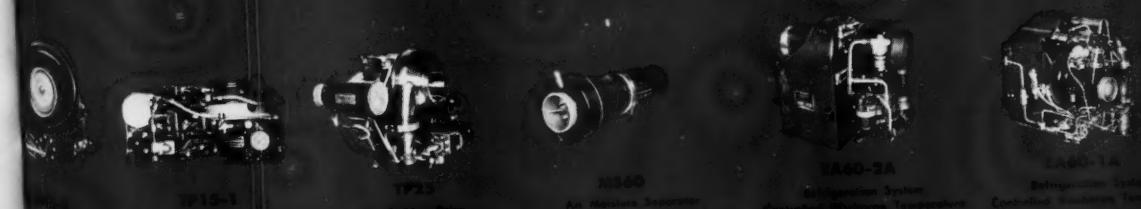

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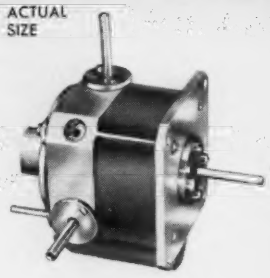

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At the conclusion of the discussi the members and guests stayed for r freshments and an opportunity to vi with the panel members.

▶ The Professional Activities Comm tee presented the second in a series specialist meetings on January 20 in t Executive Dining Room of McDonn Aircraft Corporation. Harry McKe of McDonnell, provided the group wi unclassified data and film on the effec of atomic weapons. Sixty membe and guests enjoyed the presentation J. F. Yardley reviewed the plans of th Professional Activities Committee fo the forthcoming meetings.

San Diego Section

J. M. Adamson, *Corresponding Secretary*

L. A. Payne, Design Specialist, Convair-San Diego Division of General Dynamics Corporation, spoke at the December 2 meeting on "Automatic Flight Control—Why and How." Mr. Payne discussed the need for artificial stability augmentation and fully automatic flight controls in high-speed fighters. The techniques for determining the design requirements for automatic flight control systems were reviewed, and an example of the method of mechanizing the solution to the control problem was examined. The presentation was made with schematic sketches and a working model.

▶ At the meeting of December 16, Robert J. Koenig, Senior Engineer, Hush Corporation, spoke on the subject "Aircraft Noise." Mr. Koenig discussed the psychological effect of aircraft noise from the standpoint of an observer, both inside and outside the airplane. He also touched upon the tools and methods used by an engineer to make these aircraft noises less objectionable. Mr. Koenig's talk was supplemented with some excellent slides.

Seattle Section

Louis V. Schmidt, *Secretary*

A dinner meeting was held by the Seattle Section on December 15 at the Sand Point Naval Air Station. The evening's topic was the "Local Service Airline Story" and was presented by Ernest B. Code, Vice-President of Operations, West Coast Airlines, Inc.

Mr. Code has been in charge of operations at West Coast Airlines since the company's formation in 1946. Previous to World War II, he acted as Assistant Superintendent of Operations for Northwest Airlines, Inc., and during the war years, he served as an Engineering Test Pilot with Boeing Airplane Company.

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PUBLICATION GEA-6136, "Operation Service," describes the six-point program in detail. For a copy, contact a G-E Aircraft Specialist via your nearest G-E Apparatus Sales Office. Or write *Section 232-4, General Electric Company, Schenectady 5, N. Y.*

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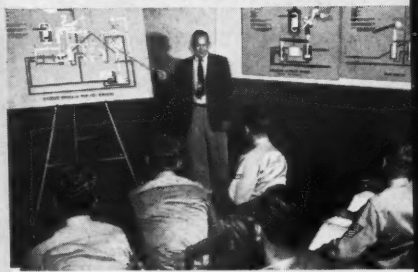
5. ENGINE SERVICE ANALYSIS. Jet service reports gathered in the field are analyzed in IBM machines to give valuable information for parts replacement estimates, also for improvement of engine design for the Armed Forces.



6. ENGINE TRAINING SCHOOL. Advanced instruction in G-E engine operation and maintenance is given on request to military and civilian personnel at the Company's Cincinnati plant.

and sometimes unrewarding task of uniting our smaller cities with the major air-route systems. Initially, these local air lines were formed to act as "feeder air lines," but their growth during the postwar years has developed an even more important role; that of intercity travel.

The challenge offered by the Pacific Northwest weather to air-line operation has been met by West Coast Airlines. This is proven by their maintenance of 97 per cent schedule completion. They now operate 15 navigational aids (in addition to CAA operated aids) in order to permit this all-weather operation. During certain times of the year, it is not unusual to operate under IFR conditions over a major portion of the air-line route on the western side of the Cascade range.

An interesting fact pointed out was that, so far, only two tire failures have occurred during landings. This attests to the care exercised in both airplane servicing and piloting, and is typical of the safe way in which equipment is handled.

A movie was also shown dealing with this subject. It summarized the speaker's most capable presentation of the local air line's operational, equipment, and economic problems.

▶ The Seattle Section was fortunate in having the noted Arctic flier, Col. Bernt Balchen, as guest speaker at the January 12 meeting. Appropriately enough, the dinner meeting was conducted at the Arctic Club. His topic was "A History of Polar Education."

Colonel William Ensley, USAF Plant Representative at the Boeing Airplane Company, introduced the evening's speaker. It was apparent that Colonel Balchen could not be introduced in a few words, since his accomplishments in Arctic flight operations have made him the world's foremost authority on Arctic flying. In the process of having logged more flight hours over snow and ice than any other man, Colonel Balchen has gained the distinction of being one of two men who has been over both poles (the other is Admiral Byrd). At the present time, Colonel Balchen is the Special Assistant for Arctic Activities in the Operational Plans Division of the Directorate of Operations, USAF Headquarters, Washington, D.C.

Colonel Balchen expressed the opinion that, whether we accept the responsibility willingly or not, the survival of the Free World depends on American air power—a power which inevitably will be focused on and operating over the Arctic perimeter of North America.

"We have to assume that the Russian Air Force has been as interested in the Arctic as we have," said Colonel Balchen. "They can read in our newspapers every day what we are doing. We find it very difficult to find out, by contrast, just what they are doing. But we do know that the Russian airmen are experienced in cold-weather operations, while ours are not.

"With the development of guided missiles, the increase in range and speed of military aircraft, the quest for an early-warning system to protect against any cross-polar attack, it is only natural that the whole military strategy of this country should be concerned with the Arctic.

"The problems are terrific, but it also is a terrific problem to maintain coexistence with the Russians until they will agree to an enforced disarmament with adequate inspection—something no totalitarian government ever wants to do."

Colonel Balchen noted that all "great circle" routes in the Northern Hemisphere pass through the polar regions. With the increase in transport plane payload and a range of up to 6,000 miles soon to be a reality, more and more commercial flights will be using northern routes as a matter of "economic common-sense," he said.

Prior to closing the meeting, a question-and-answer session was held, which disclosed that the evening's topic was indeed timely. The January meeting started out the New Year with a guest speaker whose words would be remembered for years to come.

Student Branches

Academy of Aeronautics

John A. Hope

Corresponding Secretary

The first meeting of the new year was held on January 12. Chairman Robert Zincone presided, and 34 members were present.

Final plans were discussed for a field trip to The Glenn L. Martin Company. Because of the distance involved, only 16 members felt that they would be able to go.

After the old and new business was disposed of, Student Member Calvin Felicetti presented a paper on "The Nike, U.S. New Defense Weapon." His paper was informative and was enjoyed by all.

After the showing of three movies—*Thunderstorms*, *Jet Story*, and *Oil Films in Action*—the meeting was adjourned.

Bob Zincone, *Chairman*

On January 21, the Student Branch of the IAS at the Academy of Aeronautics met at LaGuardia Airport for a field trip to The Glenn L. Martin Company. Transportation was provided by a company aircraft.

At 8:15 a.m., the 19 participants met John Dahlman, the Martin representative. Take-off was at 8:30 a.m.

Bud Dias, the pilot, gave his passengers the smoothest ride possible. Our comfort was increased by a congenial Martin steward who made refreshments available to all. The Martin plane landed on the 7,300-ft. runway of The Glenn L. Martin Airport. This airport is believed to be the largest privately operated one in existence.

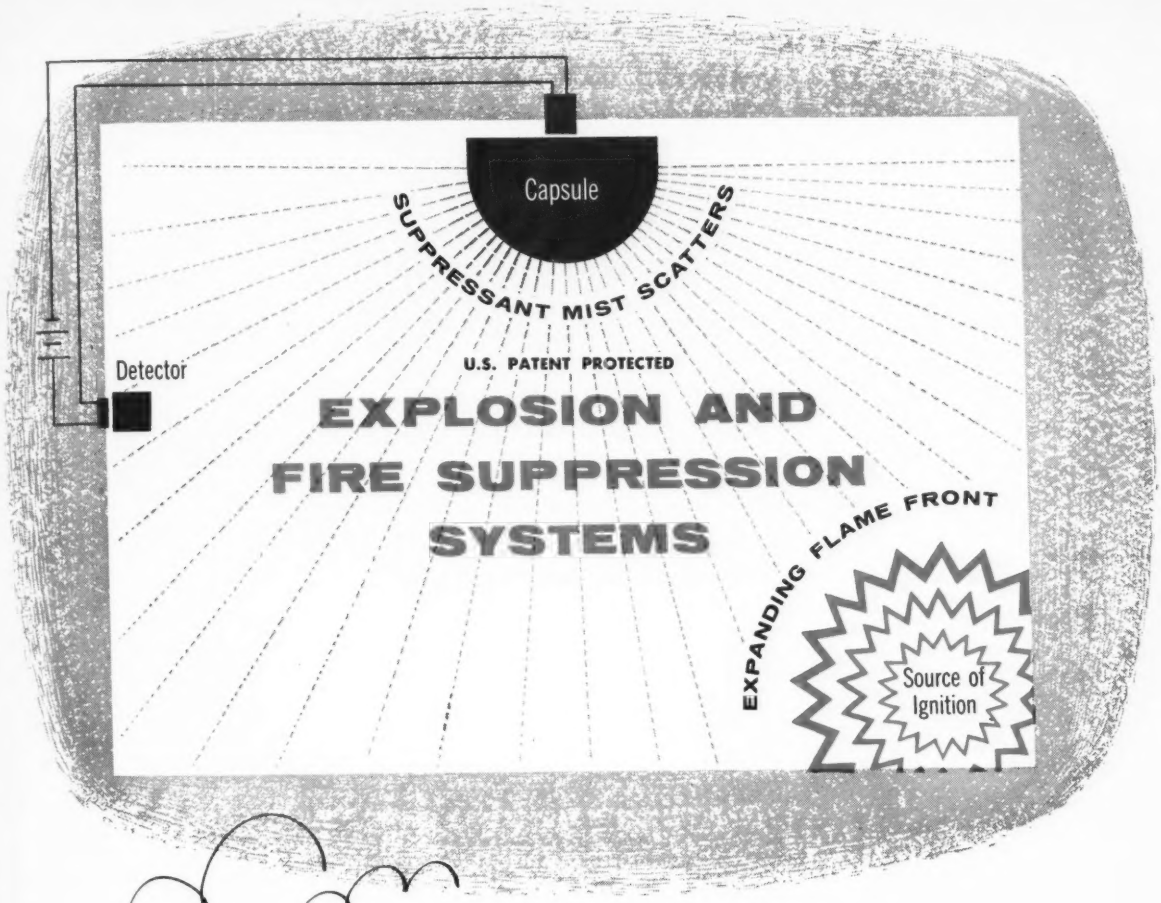
We then boarded a bus for a quick overall view of the 1,200 acres that comprise the Martin company. On our excursion, we passed the prototype SeaMaster undergoing its static tests. In reference to the SeaMaster, Martin will be able to get the credit for producing the first multiple-jet flying boat. Following the bus tour, we were taken to a reception room, where we were introduced to Mr. Gonce, a Project Engineer from the Design Integration Group, and Fred Bodnarchuk, a recent graduate of the Academy of Aeronautics. Mr. Gonce described the general construction of the Martin company and how its eight Engineering Departments are integrated to produce the Martin products. Design integration seemed to play an important role; its function is to integrate the design problems of the other groups so as to merge their efforts into a successful product.

After orientation, the IAS visitors were divided into three groups. The tour began at "A" building where various interesting manufacturing processes were seen. Of particular interest was Martin's forming operation, called Marform. Instead of using a male and a female die, the female is replaced by a dense foam-rubber block. By this process very deep sections can be formed.

Honeycomb construction plays a part in many Martin manufacturing processes. The wings of the Matador are entirely of honeycomb.

At "B" building we were taken to a balcony that was built in 42 days during normal production. From here the final construction of the P5M-2 could be seen. One can readily identify the P5M-2 by its bulbous nose. Behind this odd protrusion is one of the largest aircraft radar screens. The P5M-2 is Martin's answer to the Navy's request for an antisub aircraft.

At lunch time, Martin extended its hospitality to include an excellent meal for all. As our tour continued, it was apparent that Martin is continually striving for new methods of manufactur-



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Members of the Academy of Aeronautics Student Branch are shown before The Glenn L. Martin Company aircraft that took them on the January 21 field trip to the Martin plant.

ing that will produce lighter, stronger, and less expensive components. To date, several new manufacturing processes have been developed successfully. The remaining hour of the tour was spent in the projection room where we saw movies of the initial design, construction, and launching of the Viking rocket, and the chronological progress of Martin's aircraft through the years. Our thanks to The Glenn L. Martin Company for an extremely interesting and enjoyable trip.

Aeronautical University

John R. Lundberg, *Secretary*

Representatives from the Aeronautical University, Illinois Institute of Technology, and the University of Illinois in Chicago (Navy Pier) attended a joint meeting on January 4 to further plans for an inter-branch meeting to be held in the Museum of Science and Industry on March 2. Chairman Dailis Grauze announced the committee decision for the title of the March meeting: "Testing Techniques of Men and Machines."

Tentative speakers are a Douglas Aircraft Chief Engineer, a Convair Test Pilot, and an Aero Medic from the Rocket Sled Test Center. A roast beef dinner has been planned.

Great interest has been shown in kit aircraft. Accordingly, the University of Illinois (Navy Pier) has agreed to make arrangements for a combined meeting to which kit builders from Milwaukee will be invited.

The Branch also attended the Auto Show at the International Amphitheater in Chicago, January 13.

California State Polytechnic College

Robert Evans, *Reporter*

The January 6 meeting of the IAS Student Branch at California State Polytechnic College was called to order by Chairman Jack Gresham. Sixty-five Student Members and faculty were in attendance.

After a short business meeting, the speaker of the evening, William Werback, was introduced by Chairman Gresham. Mr. Werback was formerly with the Convair-San Diego Division of General Dynamics Corporation as a Hydrodynamicist, and is presently a faculty member of this school's Engineering Department. Mr. Werback spoke on the "Development of Dynamically Similar Models for Testing Purposes." He introduced his topic by saying that the use of models in the fields of research and engineering is not a recent innovation. Less costly and more manageable in research projects than fullsized prototypes, models were used at Convair to locate and eliminate any undesirable characteristics of water-based aircraft found during take-off and landing. These models were built to reproduce the full-scale responses of the aircraft, while being put through dynamic tests. Because of certain necessary changes in constructing these models, they are not true reproductions; however, they are dynamically similar to the full-scale prototype. Mr. Werback went on to tell the group how these models are used to solve the numerous problems encountered in high-speed water-based aircraft.

A movie from Convair entitled *The Hydrodynamic Review for 1949 and 1950*, was shown. The film showed the P5Y model and prototype being flight-tested.

The meeting was adjourned by Chairman Gresham after a short discussion period.

Case Institute of Technology

Edwin L. Cox, *Chairman*

To solve the problem of attendance at the meetings of the professional societies at Case, the student branches of ASME, SAE, and IAS have gotten together on a program of joint meetings. On the second Tuesday of each month, one of the three societies will sponsor the meeting, on a rotating basis.

On January 11 at a meeting sponsored by the Student Branch of IAS, A. O. Tischler, Research Scientist, Lewis Flight Propulsion Laboratory, NACA, was the principal speaker. Mr. Tischler spoke on the applications of the rocket engine. His talk included a brief history of the rocket, a view into the technical aspects of rocket theory, and a discussion of the problems encountered in planning a rocket trip around the moon. The meeting was successful and indicates that the programing of the joint societies is working out most satisfactorily.

Attending this meeting were 50 students and guests, representing the three societies.

Indiana Technical College

Bernard E. Heyl, *Secretary*

Chairman John Wright presided over the meetings which were held on December 7 and January 4 of the Winter Term. On each occasion 45 members were in attendance.

At the December meeting, business was held to a minimum to allow for the expected turnout of prospective members. However, plans were formulated for the annual banquet of the local Branch.

Student Member Norman L. Baker described his trip to the convention of the American Rocket Society.

Election of Officers for the two subsequent terms was held during the January 4 meeting. The positions were filled by: Norman Baker, Chairman; Raymond Navin, Vice-Chairman; Kerns Rowe, Secretary; and Howard Hall, Treasurer.

Committees for Tech's annual Open House were appointed. The theme of the project is to be "Progress and Peace Through Air Defense."

▶ The January 18 and February 1 meetings were attended by 32 and 31 members, respectively. On each occasion, Chairman John Wright presided.

Most of the business conducted at these meetings was concerned with the annual Student Branch Banquet and the School's annual Open House. At the latter meeting, the candidates for graduation were introduced, and an opinion poll was conducted consistent with school policies in an effort to determine the outstanding graduate of the Aeronautical Department at Tech. Included among the graduates of this term are Terry Welty, Don Poucher, Gerhard Haase, Edward Johnson, and Joe Iacova.

Student Member Norman L. Baker spoke at the January 18 meeting on "The Role of the Rocket in High Alti-

A part of the group from The Ohio State University's IAS Student Branch who participated in the January 13 field trip to Wright Air Development Center.

tude Research," and The Glenn L. Martin Company release, *Horizons Unlimited*, was shown. Honorary Chairman Ben L. Dow spoke on "Types of Aircraft Propulsion" at the February 1 meeting.

▸ William Bennett, Sales Manager for TWA's Fort Wayne office, was the guest speaker at our Banquet which was held at the Orchard Ridge Country Club. His topic was "The Romance and Realism of Air-line Employment." Prior to Mr. Bennett's talk, Professor Dow announced that Terry Welty had been chosen as the outstanding candidate for the Spring term. The award was made on the basis of scholastic and extracurricular accomplishments.

The Ohio State University

William E. Wagner, *Secretary*

The Ohio State Student Branch of the Institute of the Aeronautical Sciences held its January meeting on Wednesday, January 12, at Pomerene Hall on the Ohio State University campus. To start the meeting off, Chairman Dale Campbell introduced the Branch officers to the 20 new members attending. A picture was taken of the group for publication in the University yearbook, the "Makio."

▸ On Thursday, January 13, a group of 50 members, accompanied by Prof. Frank M. Mallett, traveled to Dayton, Ohio, to participate in a field trip through Wright Air Development Center. The members were greeted by Captain Auth and Captain Fisher, former OSU graduates, now members of the Wright Air Development Center personnel. Highlights of the trip included tours through the Powerplant Laboratory, where a Pratt & Whitney J-57 turbojet with afterburner was being tested; the wind tunnel facilities, including the Massy Memorial Tunnel; Structures Test and Analysis Section; Materials Laboratory; Electronics Components Laboratory; and the Propellers Laboratory. The group was impressed by the cordial reception received and the excellent displays shown by the WADC personnel.

Purdue University

David L. Beaver, *Secretary*

The members of the Purdue University Student Branch of the IAS were guests at the Indianapolis Section's January 11 meeting. This meeting was held at Plant #3 of General Motors Corporation's Allison Division. Ephraim Howard, Chairman of the Indianapolis Section, was the presiding officer, and G. J. Clingman, Supervisor of the Powerama exhibit, was our host from Allison. There were 96 members of the Purdue Student Branch present on this occasion.

The meeting began with a banquet in the plant dining room. After the dinner, Indianapolis Section Officers and Committee Chairmen were introduced, and Robert Landes, Chairman of the Purdue Student Branch, invited the Indianapolis Section to be our guests at a banquet scheduled for March 8.

The meeting was then adjourned to the auditorium where a film, *The Jet Story*, was shown. The program was concluded with a tour through Allison's Powerama exhibit. Several interesting features of this display were scale models of all planes using Allison engines, cutaways of the Allison J-35 turbojet engine and of the turboprop engine that powers the vertical take-off planes, a full-sized tank displaying the Allison transmission, a display of jet-engine fuel consumption at different altitudes, and the entire series of World War II Allison "1710" engines.

U.S. Naval Academy

C. M. Charneco, *Vice-Chairman*

The IAS Student Branch at the U.S. Naval Academy made an interesting and informative field trip to The Glenn L. Martin Company. The Student Members were first taken to the airfield to witness a demonstration of one of Martin's new B-57 jet bombers. Following the demonstration, the Student Members toured several shops and assembly lines and saw the production of Martin P5M-2 patrol planes and Matador guided missiles.

▸ The January 28 meeting was attended by over 600 members of the Student Branch. An excellent film on carrier operations off the Coast of Korea summarized the air war during the Korean conflict and showed numerous gun camera shots and action shots of jet aircraft in combat. Lieutenant H. Y. Davidson, Officer Representative of the Student Branch, was present; Chairman A. G. Cicolani presided at the meeting.

U.S. Naval Postgraduate School

Richard J. Peterson
Corresponding Secretary

The Student Branch met on January 12 to hear Woodrow L. Cook, Aeronautical Research Scientist at Ames Aeronautical Laboratory, NACA, present a paper on boundary-layer control.

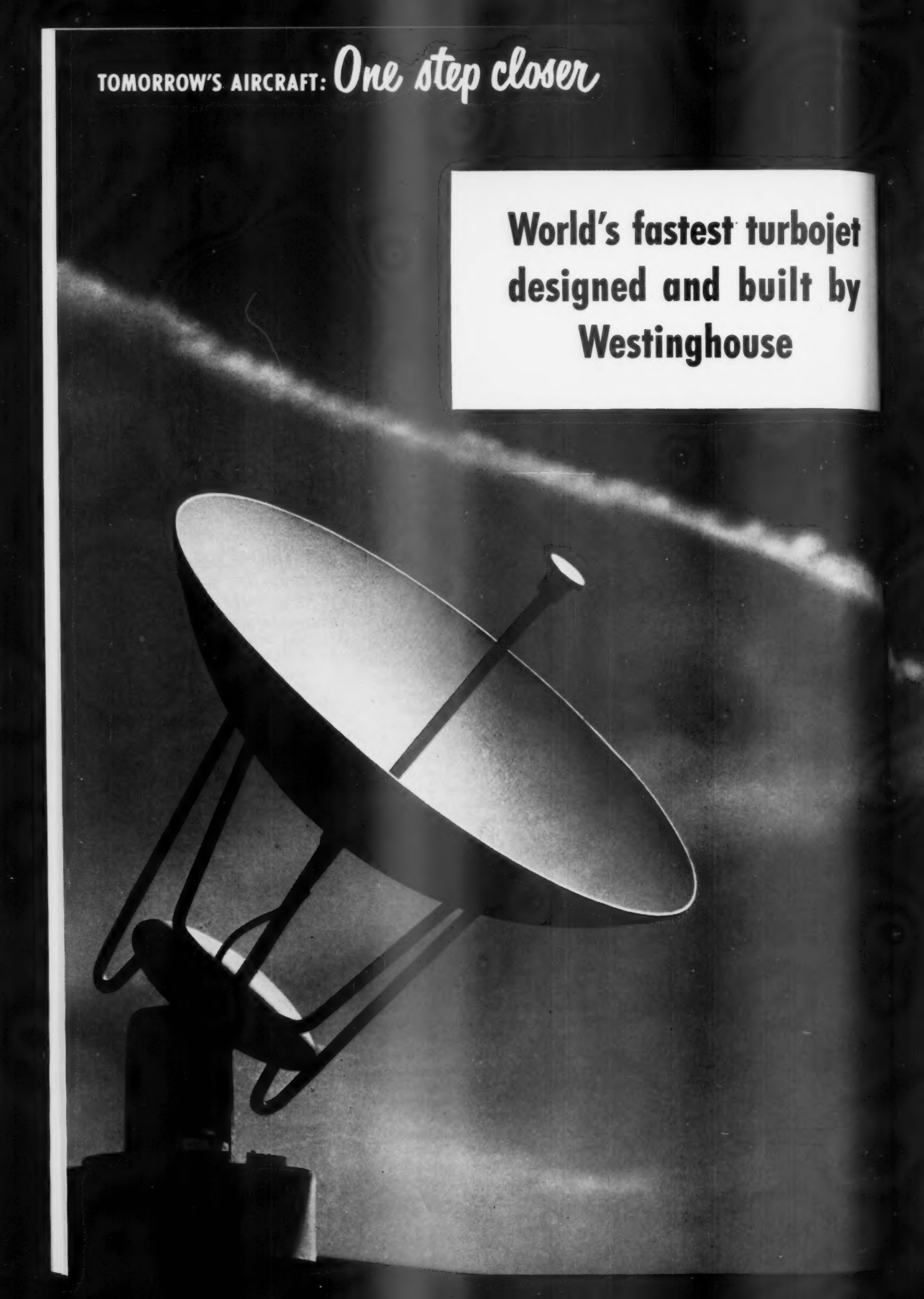
Mr. Cook spoke chiefly on the improvement of low-speed flight characteristics through the use of leading-edge suction and suction or blowing at the flap. He described current NACA investigations aimed at reducing the power requirements for such boundary-layer control methods to practical values. Mr. Cook highlighted his remarks with a short film showing a full-scale F-86 wing transition from fully stalled at 16° angle of attack to undisturbed flow with the application of leading-edge suction through a porous surface and blowing over the flap.

▸ On January 26, the Student Branch heard Don Finlay, in charge of the Preliminary Design Staff, Boeing Airplane Company, discuss the development of the Boeing jet tanker-transport and its application to both military and commercial operation. In his talk, Mr. Finlay enumerated the advantages of building an aircraft of this type as a private venture. The process is not without disadvantages, however. A film depicting the details and first flights of the Boeing 707 was shown.

University of Alabama

Fred P. Boesche, *Chairman*

The last meeting of the Fall Semester was held on January 11. Chairman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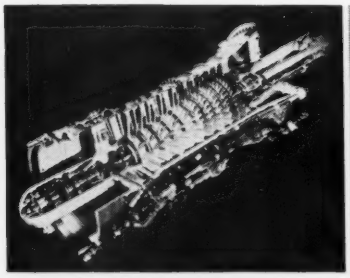

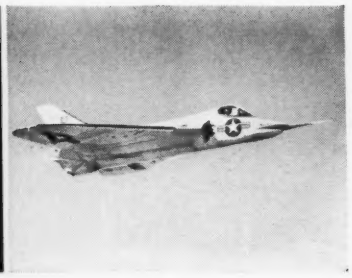

"FASTER THAN YOU THINK" is the title of a new movie about the Westinghouse family of turbojets. It presents features of Westinghouse engines which have set records for speed, endurance and availability. This includes scenes of the XF4D-1, world's record holder; and the J34 turbojet, having best specific fuel consumption in thrust and weight class. If you'd like to see the 17-minute film, check with your Westinghouse AGT representative.

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Hollub told of the coming regional meeting at Virginia Polytechnic Institute on April 7–9, and of the program planned for this event.

Charles H. Mooney then told of the Glider Club's activities during the semester. The club has already constructed a winch using a second-hand car and a drum and has been flying for the past month.

Chairman Hollub told of the Aeronautical Engineering participation in the Annual Open House. The main attraction in the display was a working model of the supersonic wind tunnel. The model and air-storage systems were made by Student Members of IAS, and the results from the running were satisfactory. Other projects shown were the model smoke tunnel, the large wind tunnel, Link Trainer, and a model airplane display.

Following these reports, Officers for the Spring Semester were elected. They are: Fred P. Boesche, Chairman; Charles C. Church, Vice-Chairman; Tony Gregoire, Secretary; and Donald Esslinger, Treasurer.

After the meeting the movie, *The Flying Wing*, was shown.

University of Illinois

John Locke, *Secretary*

The university of Illinois Student Branch of IAS held its monthly meeting Wednesday, January 12, in the Electrical Engineering Building. Fifty-three members were present, and Chairman Phil DeProtine presided at the meeting.

After a discussion of plans for the Engineering Ball and Open House, the election of officers was held. As a result, the following students will take office at the beginning of the second semester, which starts February 10, 1955: Chairman, James Kuczma; Vice-Chairman, James Piechocki; Treasurer, Louis Oling; and Secretary, James Baker. The Engineering Council Representatives are F. Samuel Snyder and John Kistenbroker.

Two films furnished by the Institute of the Aeronautical Sciences were then shown. They were *Wing Test*, a film on static testing of the wing of the Martin PBY-3, and *The Jet Story*, a film on the development of the turbojet as described by General Electric. This concluded the meeting, and refreshments were served.

University of Kansas

Marjorie Heard, *Secretary-Treasurer*

A special evening meeting of the K.U. Student Branch of the IAS was held on January 6. Chairman John Eylar presided.

The speaker of the evening was Charles E. Jackson, Chief of Structural Dynamics, Wichita Division, Boeing Air-

plane Company. His topic was "Flutter Analysis of the B-47." Mr. Jackson first gave a general description of flutter and then discussed the problems encountered in test set-up and models. His talk was illustrated with slides and a Boeing film, *Flutter of Elastic Models*.

About 50 people attended. Coffee and doughnuts were served at the close of the meeting.

University of Notre Dame

Joseph Poynton, *Secretary*

On February 4, the first meeting of the spring semester was called to order by the new Chairman, Bob Gervais. Thirty-three were present. The following new officers were introduced: Vice-Chairman, John Wilkins; Secretary, Joseph Poynton; and Treasurer, Frank Hunter. The delegate to the Engineering Advisory Board, Dave Augsten, was also introduced.

The first article of business was to amend our Constitution. Article Six, Section One, was amended to read that any student enrolled in a science or engineering course would be eligible to become a Student Member of the IAS. It was voted upon and passed unanimously by the Branch.

A report on the plans for the Engineering Open House was given by Joseph Poynton, Department Chairman, and Frank Hunter, Air Show Chairman. The report included plans for displays involving the laboratory equipment, related motion pictures, and student work on aircraft design. The Open House is planned for the weekend of May 13.

A motion picture showing the transfer of troops and equipment by air was shown and enjoyed by all.

University of Oklahoma

Carroll E. Gregg, *Secretary*

Herbert F. Herndon, Chairman, presided at the January 10 meeting of our Branch.

Paul D. Castenhol, Supervisor, Propulsion Center of North American Aviation, Inc., conducted a discussion on various means and methods of missile propulsion. Along with his discussion, Mr. Castenhol presented two films, *Looking Ahead at North American*, which illustrated some of the company production and testing methods, and *Rocket Test Sled*, which showed the work done in producing a high-speed rocket-propelled sled for testing drag chutes.

A brief outline of North American's place in industry was given by E. F. Brunetti, Engineering Personnel Representative.

Student Officers for the new semester were elected: Roy Campbell, Chairman, and Jim Maupin, Vice-Chairman.

The second Tuesday in March was selected as the date for judging the local student papers to choose the students who will represent our Student Branch at the Spring Paper Competitions.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Assicurato, Thomas, M.S. in C.E., Chief—Struct., East Coast Aeronautics, Inc.

Haldeman, George W., Special Asst. to Dir., Office of Aviation Safety, Dept. of Commerce, CAA.

Heinrick, Helmut G., Dr. Ing., Tech. Adviser, WADC, USAF, Wright-Patterson AFB.

Luoma, Arvo A., B.S. in Aero-Mech. Engrg., Aero. Research Scientist, NACA, Langley AFB.

Neihouse, Anshal I., M.S., Head of Sect., Spin Tunnel, NACA, Langley AFB.

Soehngen, Erich E., Dipl. Engr., Research Scientist, Aero. Research Lab., USAF, Wright-Patterson AFB.

Wade, W. E., Jr., B. of Ae.E., Proj. Aerodynamicist, Grumman Aircraft Engineering Corp.

Transferred to Associate Fellow Grade

Blenkush, Philip G., A.E., Chief—Prelim. Design, Radioplane Co.

Clementson, Gerhardt C., Sc.D.—Instrumentation, Lt. Col., USAF; Asst. Prof., Electrical Engrg. Dept., Resident College, USAF Institute of Technology.

Solvey, Joseph, M. of M.E., Principal Scientific Officer in Charge of Struct. Theory Group, Aero. Research Labs., Dept. of Supply (Australia).

Thayer, W. Paul, Sales & Service Mgr., Chance Vought Aircraft, Inc. (Dallas).

Townsend, Samuel J. C., B. of A.E., Chief—Propulsion, Chance Vought Aircraft, Inc. (Dallas).

Velesquez, J. L., M.Sc., Chief Engr., Airplane Projects, Weber Aircraft Corp.

Elected to MEMBER Grade

Allen, David W., B.S. in Ae.E., Aerodynamic Group Leader, McDonnell Aircraft Corp.

Amon, F. E., E.E., V-P, Parker Aircraft Co.

Beyer, Frederick J., B. of Ae.E., Sales Engr., Eastern Div., Kearfott Co., Inc.

Bingham, J. J., B.Sc.M.E., Aircraft Gas Turbine Specialist, General Electric Co. (Wash., D.C.).

Blockley, W. V., B.A., Sr. Design Engr., North American Aviation, Inc. (Los Angeles).

Bowles, Joseph P., V-P, The Greenleaf Manufacturing Co.

Brajnikoff, George B., B.S., Sr. Engr., Aerodynamics, North American Aviation, Inc. (Los Angeles).

Brown, James P., M.S. in E.E., Staff Engr., Contracts Div., Lear, Inc.

Brushfield, Guy B., Sr. Stress Officer, Aircraft Dept. R.R.E., Ministry of Supply (England).

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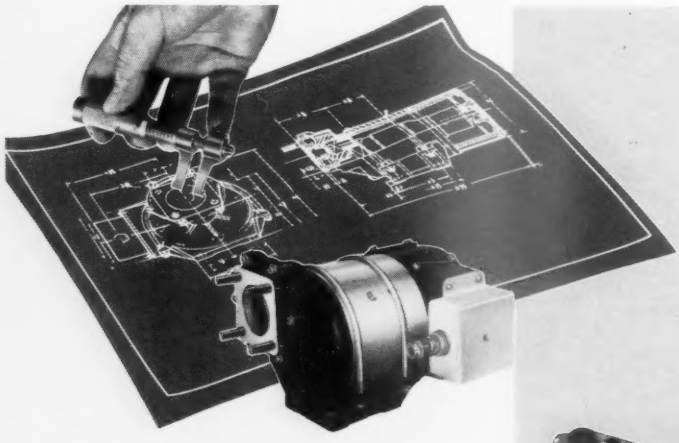

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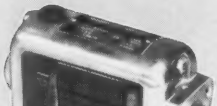

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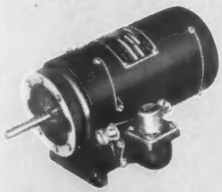

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Published Reports and Memoranda of the Aeronautical Research Council. *Gt. Brit., ARC R&M 2650,* 1954. 7 pp. 100 refs. BIS, New York. $0.65. Covering R&M's 2551–2650.

Boundary Layer & Thermoaerodynamics

Determination of Optimum Air Jet Arrangement to Delay Nose Stalling on the Articulated Nose of a Thin Wing. R. A. Wallis and G. F. Ward. *Australia, ARL AN 133,* Jan., 1954. 13 pp. Boundary-layer control system for suppressing laminar separation.

The Delay of Turbulent Separation on a Flap by the Use of Air Jets. G. A. Collins. *Australia, ARL AN 129,* Nov., 1953. 13 pp.

The Effect of Surface Roughness on the Stalling Characteristics of a Thin Aerofoil. D. G. Hurley and G. F. Ward. *Australia, ARL AN 109,* Dec., 1952. 30 pp. Experimental investigation of boundary-layer laminar separation on a model simulating the flow conditions near the nose of an NACA 64A006 airfoil at a Reynolds Number of 3.85 million.

Experiments on the Effects of Air Jets and Surface Roughness on the Boundary Layer Near the Nose of an N.A.C.A. 64A006 Aerofoil. D. G. Hurley and G. F. Ward. *Australia, ARL AN 128,* Sept., 1953. 42 pp. 12 refs.

The Irrotational Motion Outside a Free Turbulent Boundary. O. M. Phillips. *Proc. Cambridge Philos. Soc.,* Jan., 1955, pp. 220–229. Theoretical and experimental analysis for the cases where the mean properties of the fluid are approximately two-dimensional as in the turbulent boundary layer or the wake of a cylinder perpendicular to the stream.

A One-Parameter Method for the Calculation of Laminar Compressible Boundary-Layer Flow with a Pressure Gradient. J. A. Zaat. *Netherlands, NLL Rep. F. 141,* Nov., 1953. 31 pp. 16 refs.

Prediction of Shock-Induced Turbulent Boundary-Layer Separation. Artur Mager. *J. Aero. Sci.,* Mar., 1955, pp. 201, 202.

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Summary of Existing Cone Temperature Recovery Factor Data Obtained in Continuous-Flow Wind Tunnels Plus Additional Data. Leslie M. Mack. *J. Aero. Sci.,* Mar., 1955, pp. 212–214. 16 refs. CIT Jet Propulsion Lab. study of the heat-transfer problem showing that the laminar recovery factor is 0.845 ± 0.020 and the turbulent recovery factor is 0.884 ± 0.006.

Control Surfaces

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Fluid Mechanics & Aerodynamic Theory

The Character of the Equilibrium of an Incompressibile Heavy Viscous Fluid of Variable Density. S. Chandrasekhar. *Proc. Cambridge Philos. Soc.,* Jan., 1955, pp. 162–178. USAF-supported research at the U. of Chicago.

The Character of the Equilibrium of an Incompressible Heavy Viscous Fluid of Variable Density: An Approximate Theory. Raymond Hide. *Proc. Cambridge Philos. Soc.,* Jan., 1955, pp. 179–201. USAF-supported study at the U. of Chicago.

Concepts Employed in the Thermodynamics of Coupled Irreversible Flows. J. H. Keenan. *Appl. Mech. Rev.,* Feb., 1955, pp. 49–53. Analytical development of definitions of identifiable flux quantities in terms of the rate of change of an extensive property of an equilibrium region.

The Role of Fluid Mechanics in Aeronautical Development. I—Developments in Fundamental Fluid Mechanics. II—Applications to Aeronautics. III—The Role of Fluid Mechanics in Research Programs. G. N. Patterson and others. *CAI Log,* Jan., 1955, pp. 15–32. Analyses include studies of air resistance, wing theory, stability and control, and propulsion problems as applied to design requirements of high-speed, high-altitude flight.

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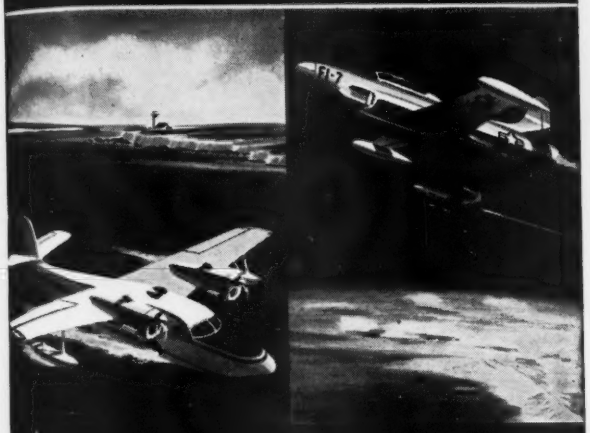

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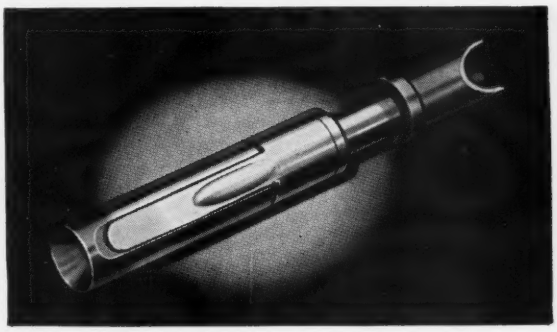

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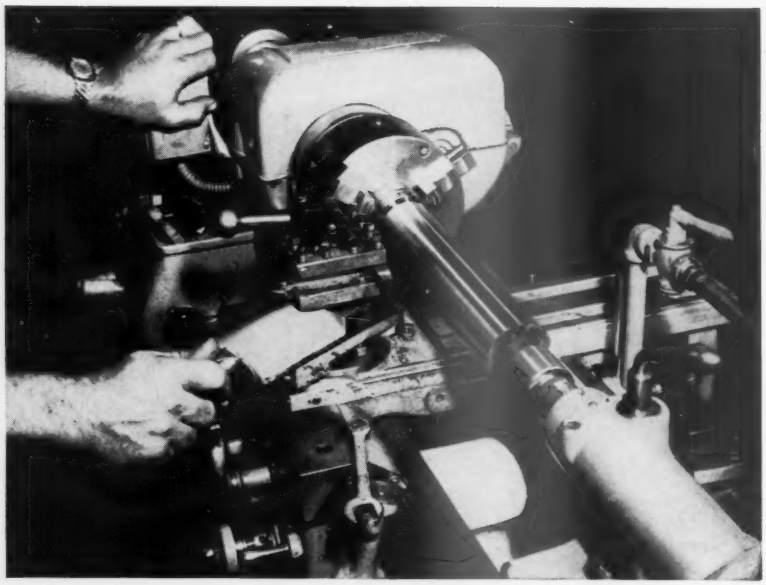

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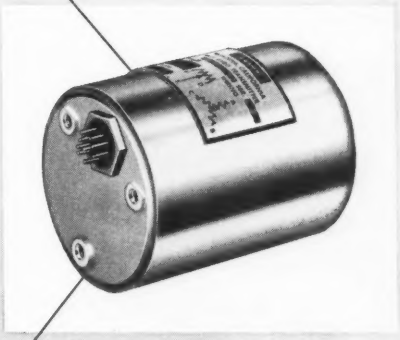

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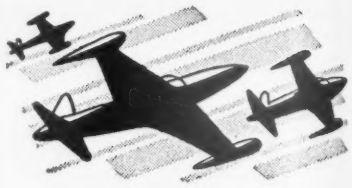

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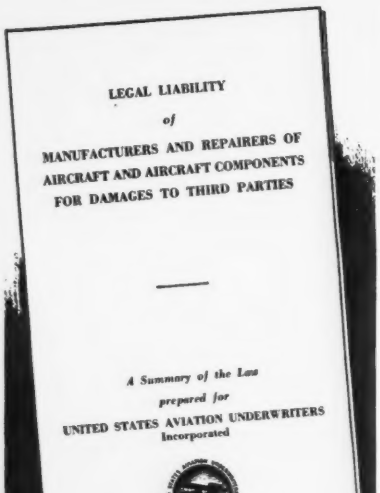
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Aeronautical Reviews — BOOKS

Modern Developments in Fluid Dynamics: High Speed Flow

Composed under the Aegis of the Fluid Motion Sub-Committee of the Aeronautical Research Council and Edited by L. Howarth with the Assistance of H. B. Squire and the late C. N. H. Lock. Oxford, at the Clarendon Press; New York, Oxford University Press, 1953. 2 Vols. 875 pp., illus., diagrs., figs. $13.50 the set.

This work represents for the most part a supplement to the work of the same name which appeared in 1938. The earlier volumes, edited by S. Goldstein, became classics in their field, and the present work extends the coverage to compressible fluids. For continuity and in order that these volumes will stand by themselves, some of the analyses and results are repeated from the earlier volumes. The editor and his collaborators had the formidable task of selecting the most important items from the extensive literature that has appeared since 1938. The coverage of many of the theoretical aspects is excellent, but the selection of experimental works often neglects the most recent results.

The first two chapters, by L. Howarth, comprise an interesting discussion and give the scope and level of the succeeding chapters—tensor derivation of the Navier-Stokes and energy equations, thermodynamic principles, dynamic similarity, one-dimensional flow, and a brief discussion of the molecular structure of gases.

The method of characteristics is the subject of Chapter III, by R. E. Meyer. The characteristic equations are derived in two dimensions, conditions near a sonic line and at the center of an axially symmetric flow are analyzed, and the methods of solution by Massau and Guderley are described and applied to some problems.

Chapter IV is in two sections: Section I, by C. R. Illingworth, treats shock waves; and Section II, by G. J. Kynch, deals with blast waves. In Section I the shock conditions are set up and solved in detail both exactly and approximately. The analysis of the structure of a shock wave is given. The intersection of shock waves is described, for the most part qualitatively. In Section II the analysis of spherical waves of high intensity is carried out from the Euler, Lagrangian, and similarity viewpoints. Both sections are devoted almost exclusively to theory.

W. G. Bickley gives in Chapter V some exact solutions of the equations of steady "homentropic" (throughout the work the term "homentropic" is used instead of the more common term "isentropic") flow of an inviscid fluid. Analyses of the vortex, source, spiral flow, flow around a corner (Prandtl-Meyer), absorption of waves as applied to the design of supersonic nozzles, flow past a wedge, and flow around a cone (Taylor-Maccoll) are given.

O. A. Saunders treats, in Chapter VI, one-dimensional flow with heat addition and friction. The simplifications are discussed, and a few experimental results are referred to, mainly for qualitative rather than quantitative verification of theory. Condensation shocks are discussed briefly.

The next two chapters treat the "Hodograph Transformation," by M. J. Lighthill, and "Approximate Methods," by G. N. Ward. The first takes up the Chaplygin and Kármán-Tsien transformations, flow around bodies with and without circulation, limit lines, branch lines, and a discussion of critical Mach Numbers. In the latter chapter the approximate methods include lifting-line theory, two-dimensional and conical flow problems, including bodies of revolution, and wing-body interference. Most of the analyses are carried out by linear methods, but some examples of higher approximations are given. The similarity laws of transonic flow are treated. Some of the analyses, notably that for the supersonic finite wing, leave out many steps.

Chapter IX, by G. Temple, gives the linearized theory of unsteady flow with some applications to wings, airfoils, and bodies of revolution in subsonic and supersonic isentropic flow. The last section of the chapter compares theoretical and experimental results for the dynamic derivatives.

Chapter X, the last in Volume 1, by A. D. Young, is entitled "Boundary Layers." The boundary-layer equations are derived and applied to a few problems. Thorough analyses of the compressible laminar boundary layer are carried out for flow over a cone and along a flat plate with zero and finite pressure gradient. Analytical as well as computing-machine results are discussed. The stability of the compressible laminar boundary layer is discussed, but little work on the effects of various influences on transition is referred to. Turbulent boundary-layer analyses according to the various assumptions are given. The chapter closes with a qualitative discussion and presentation of experimental data on shock-wave boundary-layer interaction with laminar and turbulent boundary layers.

Chapters XI and XII, the first by D. W. Holder, D. C. MacPhaill, and J. S. Thompson, on "Experimental Methods," and the second by W. A. Mair and J. A. Beavan, on "Flow Past Airfoils and Cylinders," are devoted almost exclusively to experimental results. Chapter XI contains descriptions and analyses of subsonic and supersonic wind tunnels and their components, descriptions and analyses of some of the corrections and uncertainties arising in wind-tunnel tests, and examples of measurements and methods of flow visualization. Notable omissions in this chapter are transonic and hypersonic tunnels, variable Mach Number nozzles, and techniques of measurements at low densities. Chapter XII offers test results and comparisons with available theory for subsonic and supersonic tests of airfoils, but no transonic results are given. The excellent agreement between theory and experiment which has been observed in this country in a few cases near Mach Number = 1 is therefore not reported. Effects of sweepback are treated briefly. In both of these chapters practically all of the experimental results given were reported in the literature before 1949; much of the work referred to was carried out in Germany during the war.

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The flow past bodies of revolution, specifically projectile shapes, is the subject of Chapter XIII by W. F. Cope. Pressure distributions, base pressures, stability analyses, a few measurements in the transonic region, and a brief description of the free-flight range and measurement techniques are given. Most of the literature references predate 1949 and refer to work done in England only.

The last chapter is entitled "Heat Transfer," by H. B. Squire. The work is intended to supplement that of Chapter X on boundary layers. Much of the material of the 1938 edition is included, and some additional analyses appearing in the intervening years are given. In the section on turbulent flow the various assumptions regarding changes in properties between the laminar sublayer and the turbulent layer are reviewed. Recovery factors in laminar and turbulent flows are treated theoretically, but the only data given refer to measurements reported in 1940. Useful appendixes on the energy equations and on diffusion and its analogy with heat transfer are included. It is stated that a second edition of this work will cover velocity and temperature distributions in heated jets and wakes.

Any attempt to cover the field of fluid dynamics in its present state in less than 900 pages is bound to evoke some criticism on omissions and brevity of treatment. This reviewer believes that the theoretical treatments will be of considerably more use than the portions dealing with experimental results in which the more recent literature references are in many instances omitted, and in which some important topics are not treated.

ARNOLD M. KUETHE
Felix Pawlowski Professor
of Aerodynamics
University of Michigan

Book Notes

AERODYMAMICS

Second Canadian Symposium on Aerodynamics, Proceedings; Held at the Institute of Aerophysics, University of Toronto, February 25–26, 1954. Toronto, Institute of Aerophysics, 1954. 290 pp., illus., diagrs., figs.

Contents: The Aerodynamics Involved in High Speed Wing Design, J. Chamberlain. The Development of a Turbojet Installation in a Single-Engine Fighter Aircraft, R. D. Richmond, G. Rosenthal, and F. M. Figueroa. Some Aerodynamic Characteristics of Delta Wings at Low Speeds, P. J. Pocock and W. E. Laundry. The Contribution of Aerodynamic Theory to the Understanding of Aircraft Behaviour at Transonic Speeds, B. G. Newman. Load Distribution on Supersonic Wings of Arbitrary Shape, B. Etkin and F. Woodward. On Some Problems of Unsteady Wing Theory, A. Robinson. Drive and Operation of Large Intermittent Wind Tunnels, J. Lukasiewicz. Optimum Design of Finned Projectiles, R. N. Cox. Mechanics of Rarefied Gases, G. N. Patterson. A General Approach to Turbo-Machinery, D. L. Mordell. Turbulent Boundary Layers, Francis H. Clauser. On the Reflection of a Shock Wave from an Open End of a Duct, George Rudinger. An Experimental Study of Shock Wave Refraction, A. Ford and I. I. Glass. Some Experimental and Theoretical Aspects of Shock Wave Attenuation, I. I. Glass and W. A. Martin. Lift and Moment of Low Aspect Ratio Wings in Incompressible Unsteady Flow, J. Leyds. Non-Linear Waves in Solids, G. L. Cann. A Technique of Manufacture of Supersonic Nozzles, J. G. Laberge and L. T. Conlin. Increase of Engine Icing due to Inertia Separation of Cloud Droplets in High Speed Flight, D. A. S. Millar.

AIRCRAFT OPERATION

NACA Conference on Some Problems of Aircraft Operation; November 17 and 18, 1954, at the Lewis Flight Propulsion Laboratory. Washington, National Advisory Committee for Aeronautics, 1954. 195 pp., illus., diagrs., figs.

Contents: Take-Off and Landing Operations: Thrust Control Problems in a Turbojet Engine, John C. Sanders. A Means of Detecting Performance Deficiency in Take-Off, Joseph W. Wetmore. Inadvertent Thrust Reversal on Multi-Engine Airplanes, Kenneth W. Goodson. Principles of Thrust Indicators for Pilots' Use, A. W. Vogeley. Velocity and Persistence of the Trailing Vortices of an Airplane, Christopher C. Kraft, Jr. Some Factors Affecting Airplane Stopping Distance During Ground Roll, John A. Zalovcik and Richard H. Sawyer.

Atmospheric Turbulence and Fatigue: Review of Flight Data on Atmospheric Turbulence, Harold B. Tolefson and Harry Press. The Influence

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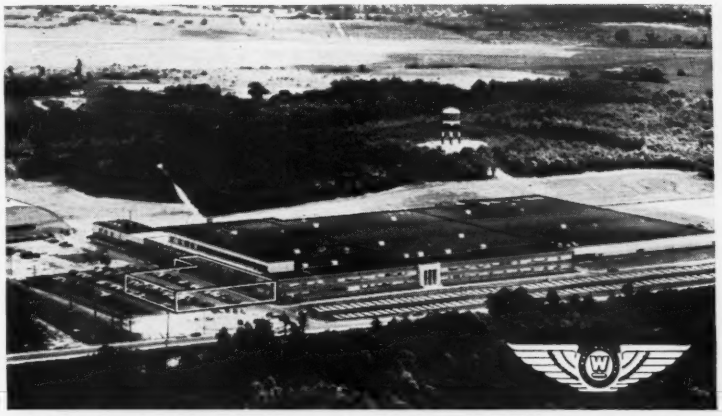

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Airplane and Helicopter Handling Qualities: Power Control Systems and Control Feel Devices for Satisfactory Handling Qualities, William H. Phillips. Helicopter Handling Qualities in Contact and Instrument Flight, John P. Reeder and James B. Whitten.

Airplane Accident Survival: Effects on Ditching Characteristics of Some Transport Airplane Design Trends, W. C. Thompson and J. O. Windham. Human Survival Considerations in Airplane Crashes, Gerard J. Pesman. Research on Crash Fires of Jet Airplanes, I. Irving Pinkel and Solomon Weiss.

Airplane Noise: Effects of Some Variables on the Near Field Noise from Propellers, Harvey H. Hubbard. Investigations of Noise Reduction Devices for Full-Scale Jet Engines, Newell D. Sanders and Edmund Callaghan.

Airplane Icing: Icing Conditions to Be Expected in the Operation of High-Speed, High-Altitude Airplanes, William Lewis. Some Considerations of the Need for Icing Protection of High-Speed, High-Altitude Airplanes, Uwe von Glahn.

MATHEMATICS

Transactions of the Symposium on Fluid Mechanics and Computing; Held at New York University, April 23–24, 1953. The First Symposium on Applied Mathematics sponsored by the American Mathematical Society and Office of Ordnance Research, U.S. Army. New York, Interscience Publishers, Inc., 1954. 243 pp., diagrs., figs. $5.00.

Contents: Mathematical Methods in Compressible Flow Theory, M. J. Lighthill. Boundary Layer Problems in Applied Mathematics, G. F. Carrier. Fourier Synthesis of Homogeneous Turbulence, Garrett Birkhoff. One-Dimensional Anisentropic Flows, G. S. S. Ludford and M. H. Martin. Approximate Methods for Computing Flow Fields, J. H. Giese. Results and Conjectures in the Mathematical Theory of Subsonic and Transonic Gas Flow, Lipman Bers. The Singular Solutions and the Cauchy Problem for Generalized Tricomi Equations, Alexander Weinstein. Remarks on the Theory of Partial Differential Equations of Mixed Type and Applications to the Study of Transonic Flow, P. Germain. Discussion on Transonic Flow, R. von Mises. Role of Computing Machines, John von Neumann. Some Problems Solvable on Computing Machines, Mark Lotkin. Weak Solutions of Non-Linear Hyperbolic Equations and Their Numerical Computation, Peter D. Lax. Computation of One Dimensional Compressible Flows Including Shocks, L. H. Thomas. The Deformation of a Thin Material Shell of Non-Uniform Thickness by a Detonation Wave, G. E. Hudson. Measurement of Spherical Shock Waves, Hubert Schardin.

METALS & ALLOYS

Symposium on Effect of Cyclic Heating and Stressing on Metals at Elevated Temperatures; Held in Chicago, June 17, 1954. (Special Technical Publication No. 165.) Philadelphia, American Society for Testing Materials, 1954. 175 pp., illus., diagrs., figs. $3.00.

Contents: What We Need to Know About Creep, John E. Dorn and Lawrence A. Shepard. The Problem of Thermal Stress Fatigue in Austenitic Steels at Elevated Temperatures, L. F. Coffin, Jr. Effect of Temperature Cycling on the Rupture Strength of Some High-Temperature Alloys, James Miller. Experiments on the Effects of Temperature and Load Changes on Creep Rupture of Steels, G. V. Smith and E. G. Houston. Effects of Cyclic Overloads on the Creep Rates and Rupture Life of Inconel at 1,700 and 1,800 F., R. H. Caughey and W. B. Hoyt. The Creep-Rupture Properties of Aircraft Sheet Alloys Subjected to Intermittent Load and Temperature, G. J. Guarnieri. Constant and Cyclic-Load Creep Tests of Several Materials, Ward F. Simmons and Howard C. Cross. The Effect of Composition on the Scaling of Fe-Cr-Ni Alloys Subjected to Cyclic Temperature Conditions, H. L. Eiselstein and E. N. Skinner. Summary, D. N. Frey.

Symposium on Fretting Corrosion; Held in New York, June 25, 1952. (Special Technical Publication No. 144.) Philadelphia, American Society for Testing Materials, 1953. 84 pp., illus., diagrs., figs. $2.75.

Contents: The Current Status of Fretting Corrosion, W. E. Campbell. Fretting Corrosion Tendencies of Several Combinations of Materials, J. R. McDowell. Influence of Fretting Corrosion on the Fatigue Strength of Fitted Members, Oscar J. Horger. Effect of Lubricants in Minimizing Fretting Corrosion, E. W. Herbek, Jr., and R. F. Strohecker. Test Equipment for Evaluating Fretting Corrosion, H. H. Uhlig, W. D. Tierney, and A. McClellan. General Discussion.

STRUCTURES

Proceedings of the Society for Experimental Stress Analysis: Vol. 12, No. 1. Edited by C. V. Mahlmann and W. M. Murray. Cambridge, Society for Experimental Stress Analysis, 1954. 226 pp., illus., diagrs., figs. $6.25.

Contents: Stress Concentration in the History of Strength of Materials, S. Timoshenko. Structural Analysis by Electrical Analogy, G. W. Riesz and B. J. Swain. Precise Investigation of Two Model Columns—Experimental Technique, J. R. Benjamin. Discussion of Paper Entitled: "Ballast Circuit Design," J. H. Meier. Stresses in Oval Tubes under Internal Pressure, J. C. Weydert.

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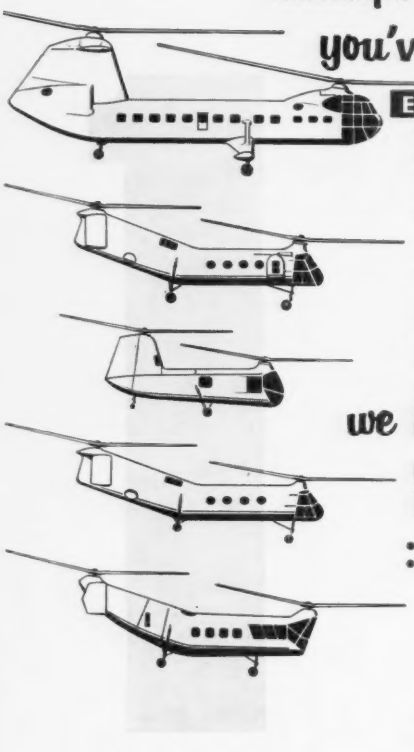

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A New Cementable Material for Two- and Three-Dimensional Photoelastic Research, M. M. Frocht and Hui Pih. A Photoelastic Study of Multibarrel Conduits, B. Pant and J. B. Mantle. Application of Experimental Stress Analysis to Torsion Research, C. E. Work and T. J. Dolan. A Method of Deriving Residual Stress Equations, J. W. Lambert. Letter to the Editor: S.A.E. Division 4 Program on the Experimental Determination of Residual Stresses, E. S. Rowland. Photoelastic Stress Analysis for an Edge Crack in a Tensile Field, D. Post. A Piezoelectric Strain Gage, E. A. Ripperger. Vehicle Vibration and Stress Testing, H. W. Larsen. Letter to the Editor: Analysis of the Cantilever Beam by Means of the Laplace Transform, S. B. Williams. An Analysis of the Phenomenon of High Temperature Creep, O. D. Sherby and J. E. Dorn. Metallurgical Aspects of Strength at Elevated Temperatures, G. V. Smith. Experimental Analysis of the Buckling of Cylindrical Shells Subjected to External Hydrostatic Pressure, E. Wenk, Jr., R. C. Slankard and W. A. Nash. The Use of Photometric Devices in the Solution of the General Three-Dimensional Photoelastic Problem, M. M. Frocht, Hui Pih, and D. Landsberg. A New Photoelastic Interferometer Suitable for Static and Dynamic Measurements, D. Post. Residual Stresses in a Strip in Terms of Strain Changes During Electropolishing, D. O. Leeser and R. A. Daane. An Automatic Load Control for Fatigue Test Equipment, E. K. Benda and R. A. Gallant. Further Notes on Automatic Control as Applied to Fatigue Test Equipment, T. A. Hewson.

WIND TUNNELS

Wind-Tunnel Testing. Alan Pope. 2nd Ed. New York, John Wiley & Sons, Inc., 1954. 511 pp., illus., diagrs., figs. $8.50.

In this edition there are new chapters covering testing of nearsonic, transonic, supersonic, and hypersonic speeds. Helicopter rotor testing is treated in an extensive fashion, and nonaeronautical uses for wind tunnels are suggested. Data and procedures have been revised to conform with latest practices, and the book is now about 30 per cent longer than the previous edition. The author is Supervisor, Experimental Aerodynamics Division, Sandia Corporation.

YEARBOOKS

Jane's All the World's Aircraft, 1954-55. Compiled and Edited by Leonard Bridgman. New York, The McGraw-Hill Book Company, Inc., 1954. 407 pp., illus., diagrs. $23.

The present edition has undergone the usual complete revision, involving the complete resetting of all type matter and the introduction of over 400 new illustrations. The book is divided into eight sections, as follows: military aviation, civil aviation, civil air-line operators, airplanes, gas-turbine engines, piston engines, airships, and indexes. The airplane section, which comprises 264 pages, contains descriptions and specifications of aircraft produced in 30 countries and includes 625 illustrations, of which 362 are new. It has been corrected to July 31, 1954. The American section occupies 94 pages, 13 more than last year, while Great Britain takes up 72 pages, 11 more than in the last volume. France is third with 30 pages. The Russian pages have been revised and supplemented, but the editor advises caution regarding information on Russian aircraft. For the first time in the engine section, the number of pages devoted to gas-turbine engines exceeds those dealing with piston engines. Of the total of 67 pages in this section, 36 are needed to cover the gas-turbine engines produced by eight countries. In all, there are 110 engine illustrations, of which 68 are of gas turbines. Four separate indexes are provided, covering aircraft, helicopters, gas-turbine engines, and piston engines. In addition to references to all items in this edition, each index contains references to every aircraft and engine described in the eight previous editions, going back to and including 1945–1946.

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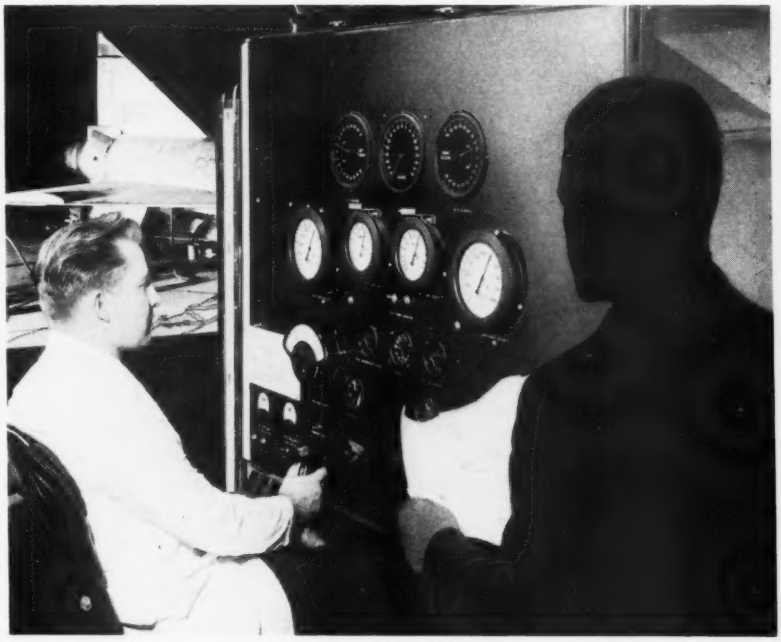

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